JOURNAL

OF THE

FRANKLIN INSTITUTE

OF THE STATE OF PENNSYLVANIA,

FOR THE PROMOTION OF THE MECHANIC ARTS.

VOL. CXXIV. SEPTEMBER, 1887. No. 3.

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THE CHEMICAL BASIS OF PLANT FORMS.

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[*A Lecture delivered before the* FRANKLIN INSTITUTE, *January 24, 1887.*]

The boundary between the mineral and vegetable kingdom is not a definite line. The individual of the one encroaches upon the dominion of the other. The terms "non-living" and "living matter" are only relatively accurate. [1]"Nature in all its manifestations constitutes a unity," * * * and "all matter is in a sense living."

Through chemical evolution a condition of matter obtains favorable for functional activity or life. This state may be described [2]"as a colloidal albuminoid united with more or less water." Its

[1] *Mineral Physiology and Physiography.* By T. Sterry Hunt. Boston, 1886, p. 18.

[2] *Ibid.*

simplest expression is found in the low forms of plants, slime-mould for example. This colloidal basis of life is protoplasm, a chemical compound of complex constitution, very unstable, and manifesting when alive certain properties called vital or "biotic."[1]

Active chemical changes are inseparably associated with both living and dead protoplasm. Synthetical or progressive processes prevail in life, analytical or retrogressive in death.

Absorption, metabolism, excretion, reproduction, contractility, automatism, and irritability are the properties of living matter; disorganization and dissociation those of dead matter.

Chemists have to discover the subtle differences between the chemical equation of living and dead protoplasm.

I wish to speak of some of the chemical compounds of plants, or more properly the chemical forms, since the structure of all plants is built up of chemical constituents. This subject is as extensive as the genera and species of the vegetable kingdom.

Last August,[2] I read a paper on certain chemical constituents of plants considered in relation to their morphology and evolution. The facts cited tended to show a chemical progression in plants, and a mutual dependence between chemical constituents and change of form.

Among the conclusions reached, were the following:

(1.) A similarity of one or more chemical constituents is to be found in all plants which are equally developed, and on the same evolutionary plane.

(2.) The evolution of chemical constituents follows parallel lines with the evolutionary course of plant forms, the one being intimately connected with the other, and consequently chemical constituents are indicative of the height of the scale of progression, and are essentially appropriate for a basis of botanical classification; in other words, the theory of evolution in plant life is best illustrated by the chemical constituents of vegetable forms.

Chemistry will aid us to comprehend the laws of evolution controlling plant forms. Evolution should also apply to chemical compounds as well as to morphology, since the latter can be shown to depend upon chemistry in general.

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[1] Dr. T. Sterry Hunt.

[2] Chem. Section Am. Assoc. for the Adv. of Science. Buffalo, 1886. Abstract, *Bot. Gazette, xi*, No. 10, Oct., 1886.

We have no certain knowledge of the precise chemical changes which take place in transforming carbon, hydrogen, oxygen, nitrogen, sulphur and other elements into the starches and proteids. We know, however, certainly the necessary conditions for many of these changes. The law controlling the absolute relation or the connective link between the form of a plant and its chemical composition is undetermined. But investigations in plant chemistry have not been conducted with this end in view. The facts which I have to offer to sustain the theory of a possible relation between plant forms and chemical compounds may seem to some inadequate, but no other explanation than the one offered to account for these statements has been suggested.

The chemical composition of the cell contents and wall has been determined in many plants; also of their roots, leaves, flowers and fruits.

Most of the ash constituents essential or injurious to the growth and development of plants are known, and also the variations in growth caused by the presence or absence of certain inorganic compounds.

The chemical changes through which many plants pass from the germination of their seed to maturity and decay are also known, each separate stage of growth showing a distinct chemical composition or a predominance of some one chemical compound.

It should be especially noted that some chemical compounds occur in certain species of plants and do not occur in others. Certain classes of compounds are found widely distributed through the plant kingdom, accompanied by correlated morphological characters. Some one compound, as saponin, will be found with similar botanical characters in plants of distinct genera and families, on the same plane of evolution or development.

It cannot be the result of accident, that cinchona and related plants contain quinine; and other plants distributed through the vegetable kingdom their own typical compounds. Nor can it be the result of accident or changes produced by climate or other causes, that an absence of some one or more compounds is accompanied by a modification of the exterior of the plant.

Before taking up the consideration of the above statements in detail, it may be well to study briefly two properties[1] of living protoplasm, namely, absorption and metabolism.

[1] *Lectures on the Physiology of Plants.* By S. H. Vines. Cambridge, 1886.

The seeds of plants are the store-houses of a certain amount of latent energy or life, elaborated by the parent plant and stored up in the form of complex chemical compounds. Under suitable conditions of warmth and moisture, certain chemical changes take place within the seed. The latent energy becomes active, and the seedling grows, feeding upon its food supply until it has exhausted its store.

At this stage the little plant must seek from without its food, from the atmosphere and the soil. The soil is of varying and complex composition, containing between its particles gases and moisture. The air which surrounds the leaves of land plants is a mixture of nitrogen and oxygen with small quantities of carbon-dioxide, ammonia, varying quantities of aqueous vapor and occasionally traces of nitric acid.

The elements from these media are absorbed by different parts of the plant, and there is a difference in the manner of absorption by fungi, parasites, air plants, and green plants. However, the elements which are absolutely essential for the nutrition and maintenance of the life of all plants are carbon, hydrogen, oxygen, nitrogen, sulphur, phosphorus, potassium, calcium, magnesium, iron in the case of green plants, and in certain cases chlorine.

It is characteristic of plants that they must absorb their food in the fluid form. The absorbent organs of plants are the roots for water and salts in solution, and the leaves for gases. In the lower plants, where there are no roots nor leaves, water or substances in solution and gases are absorbed, either directly by the cells of the Thallus or by root hairs. Among the higher plants, the root hairs and the uncuticularized epidermal cells of the younger roots are active in absorbing material from the soil. Any part of the plant, if immersed in water, will absorb a smaller or a larger quantity of it; as, for instance, cut flowers placed with their cut ends in water will absorb, for a time, sufficient to prevent withering. The absorption of gases in higher plants is by means of the leaves, for it has been found that carbon-dioxide is absorbed from the air by those organs which are green and contain chlorophyl, and in experiments where the carbon-dioxide of the air was cut off from the leaves, though it was supplied to the roots, it was found that the plant could not live long. It has also been found that the presence of carbon-dioxide in another part of the plant does not contribute to the formation of starch in the leaves.

Green plants obtain their carbon from the carbon-dioxide of the air. Plants which do not contain chlorophyl, obtain their carbon by the absorption of complex organic substances. Green plants can absorb complex carbon compounds, and it has been proved, by direct experiment, that they can take up these complex substances when supplied to their roots.

Darwin[1] has shown that the insectivorous plants, by means of their modified leaves, absorb complex compounds, and that these are of importance in their nutrition. Flies and other small insects may often be found clasped in the tentacles of the *Drosera*, and in those experiments small pieces of meat, when placed on the leaves, were dissolved after a time by the secretions of the leaf glands and absorbed.

Hydrogen is absorbed by all plants in combination in the form of water or ammonia and its compounds, or in the complex substances mentioned above.

Oxygen is taken up by plants free or in combination in water or in salts. The free oxygen is especially concerned in destructive metabolic processes. The large quantities of this gas absorbed by plants, and especially by Fungi, show conclusively its consumption in metabolic processes.

The process known as the respiration of plants is the absorption of oxygen and the exhalation of carbon-dioxide.

The researches of Garreau[2] show that two distinct processes are in operation when leaves are exposed to the light, in the one oxygen is absorbed and carbon-dioxide is exhaled; in the other, carbon-dioxide is absorbed and oxygen is exhaled. When the leaves are exposed to a very bright sunlight, carbon-dioxide is absorbed and oxygen is exhaled, and the activity of these processes is so much greater than the absorption of oxygen and the exhalation of carbon-dioxide, that it appears as if the former only were in operation.

Gases, like solids, can only be assimilated in solution, and as they are soluble in water, the cell-walls of submerged plants may absorb them, and the sap near the surface of land plants will dissolve the gases from the atmosphere. The sap of plants contains in

[1] *Insectivorous Plants.*

[2] *Ann. d. Sci. Nat.*, Ser. 3, t. *xv.*

solution carbon-dioxide, oxygen, and also a certain amount of free nitrogen. That this nitrogen does not enter into the metabolism of the plant seems completely decided by the experiments[1] of Lawes, Gilbert, and Pugh; but the more recent experiments of Atwater[2] and Hellriegel[3] should be compared in this connection, and the matter cannot be said to be definitely settled.

I can only enumerate in this connection, without going into the subject, the possible sources[4] of the nitrogen supply:

(1.) Organic, nitrogenous matter.

(2.) The ammonia of the air, and of the ocean.

(3.) The nitrous and nitric compounds formed by combustion and by electric discharges.

(4.) Nitrogen fixed in the soil by microbes.

(5,) The free nitrogen of the atmosphere.

(6.) Mineral nitrates.

The sap which is continually flowing through living plants, is a watery fluid, holding in solution mineral matters, gases, and organic substances. The root hairs of plants penetrate the particles of soil and absorb the moisture from a film which surrounds each particle known as hygroscopic water. In thallophytes, the absorption is effected by the cells of the Thallus, and in Orchids a membrane invests the air roots especially adapted for the purpose. The distribution of water takes place, at least to some extent as its absorption, it passes by osmosis from cell to cell, as it passes originally from without into the superficial cells of the plant. The direction of this movement is not necessarily constant. The proportion of water in each cell varies, and the tendency to establish a fluid equilibrium will cause a current towards those tissues which are deficient. These statements apply equally to gases and other substances held in solution, which are needed for the continuance of the chemical and physical changes going on in the living cells of different parts of the plant.

The changes are more active for different substances in different

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[1] *Phil. Trans.*, 1860.

[2] *Amer. Chem. Jour., viii*, Nos. 5 and 6.

[3] *Zeit. d. Ver. f. d. Rübenzucker Industrie*, Nov., 1886.

[4] "The Economical Aspect of Agr. Chemistry." By H. W. Wiley. *Proc. A. A. A. S., xxxv*, 1886.

parts of the plant. The mineral substances absorbed by the roots pass up to the leaves, where they are concerned in the constructive metabolism going on in those organs. The products of these processes pass from the leaves to parts of the plant which are actively growing, and where plastic material is required, or to the seeds or other organs in which organic stores are being laid up.

If the stems or plants are cut in the spring, a flow of sap proceeds from the cut surface of that portion of the stem which is connected with the roots. This fact was investigated by Hales;[1] he concluded that there is "a considerable energy in the root to push up sap in the bleeding season." This force is termed the root pressure, and is the measure of the absorbent activity of the root hairs. The root pressure is not only manifested by causing the flow of sap; it also may cause the exudation of drops of sap on the surface. There is a marked periodicity in the flow of sap, which is not due to the immediate result of variations in external conditions, but is inherent in the absorbent cells themselves.

The current travels from the roots to the leaves through the lignified cell walls of the wood of the plant. The activity of the exhalation of watery vapor from the plant is not the same from their surfaces. The refreshing effect of a shower on withered leaves is due to the moisture penetrating the soil and being absorbed by the root hairs. From experiments[2] it has been shown that if the air is very moist and the leaves dry, that the leaf surfaces may absorb a little water.

The cuticle offers a certain amount of resistance to the passage through it of vapor which is due to resinous or waxy substances contained in it. The Mexican *Ocotilla*[3] offers a striking example. It grows in very dry and exposed parts of the country, where rainfalls are infrequent. The bark is chiefly composed of wax and resinous substances.

Other substances, as well as water, can be absorbed by leaves,[4]

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[1] *Statical Essays*, 1, 1769 (4th Edition).

[2] Detmer and Boussingault.

[3] H. C. De S. Abbott, *Proc. A. A. A S., xxxiii.* (*Am. Journal Pharm.*, Feb., 1885.)

[4] Boussingault; *Ann. Chem. et Phys.*, sér. V, *xiii*; also, *Agronomie*, VI, 1878. Mayer; *Landwirthschaftl. Versuchs-Stat., xvii*, 1874.

experiments having shown that if a drop of calcium sulphate solution be placed on a leaf, it will have disappeared in the course of a few hours. This is more rapid when placed on the under surface. Though it seems that leaves may absorb water and substances in solution under certain circumstances, the especial absorptive function of leaves is the absorption of gases, as has been already explained.

The subject of the ash constituents of plants is a very important one in this connection. The essential mineral constituents of plants have already been mentioned: silicon, fluorine, manganese, sodium, lithium, rubidium, cæsium, barium, aluminium, zinc, copper, titanium, iodine, and bromine have also been found among the ash ingredients of certain plants.

The method of absorption of soluble mineral salts has already been described. A solution of insoluble salts is brought about in a different way. A soil rich in organic matter is always charged with carbon-dioxide, and this gas is also given off by the roots of living plants. Water containing this gas is able to dissolve calcium carbonate and some silicates, which are insoluble in pure water. The presence of certain soluble salts in the soil brings about a decomposition and renders the insoluble salts more readily soluble. Finally, the insoluble salts are brought into solution by means of the acid sap which saturates the cell wall of the root hair. This acid is not carbonic acid, for its reddening of litmus paper is permanent.

It has been shown by experiment that the chemical elements are not universally absorbed by roots in their combinations in the soil.

The wide differences in the composition of the ashes of plants show that each plant is endowed with a specific absorbent capacity. It is upon this fact that the "rotation of crops" in farming depends. A gramineous plant[1] is able to withdraw relatively larger quantities of silica from the soil than a leguminous plant. The latter can only do so to a very slight extent.

The absorbent capacities of nearly allied species are very different; again, individuals of the same species yield different ash compositions, depending upon their vigor; and the absorbent capacity of the plant varies at different periods of its life. It has

[1] Wolff; *Aschen Analysen*, 1871.

been stated that "similar kinds of plants, and especially the same parts of similar plants, exhibit a close general agreement in the composition of their ashes, while plants which are unlike in their botanical characters are also unlike in the proportions of their fixed ingredients."[1] If an ash constituent can pass through a cell wall, its absorption will take place independently of its use or harmfulness to the plant, but the absorption of essential inorganic constituents will depend upon its relation to the metabolism of the plant.

The ash constituents of a plant increase from the roots upwards to the leaves, a fact showing that the leaves are the organs in which more especially active chemical changes take place.

The ash ingredients are usually present in each plant cell; in the cell wall, imbedded in the cellulose, and partly in the contents of the cell. The salts of the alkaline metals and of the sulphates and the chlorides of magnesium and calcium occur in the solution of the sap. Silica and phosphates of calcium and magnesium are mostly insoluble and exist in the tissues of the plant.

Water culture experiments[2] have shown the essential ash ingredients. Potassium, like phosphorus, is always found in relation with living protoplasm. If[3] the plant was not supplied with potassium, it grew very little, and very little starch was formed in the chlorophyl corpuscles of the leaves. On the addition of potassium chloride, the starch grains became more numerous in the leaves, and made their appearance in other parts of the plants. Potassium, doubtless, plays an important rôle in the formation and the storing up of carbo-hydrates, for the organs in which these processes are active, as the leaves, seeds and tubers are found to be the richest in this element.

It has been observed that cæsium[4] and rubidium can replace potassium in the food of certain *Fungi* (mould, yeast and bacteria).

Salm-Horstmar describes[5] some experiments, from which he infers that minute traces of lithium and fluorine are indispensable

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[1] *How Crops Grow.* By S. W. Johnson. London, p. 145.

[2] Nobbe, Siegert, Wolff, Stohmann, Sachs, and others.

[3] Nobbe; *Die organische Leistung des Kaliums*, 1871.

[4] Naegeli; *Sitzber. d. Akad. d. Wiss. zu München*, 1880.

[5] *Jour. für Prakt. Chem.*, 1884, p. 140.

to the fruiting of barley. The same investigator has concluded that a trace of titanic acid is a necessary ingredient of plants.

Zinc[1] is also a frequent constituent of plants growing about zinc mines. Certain marked varieties of plants are peculiar to, and appear to have been developed by such soils, as the Violet, *var calaminarias* and Penny-cress. In the leaves of the latter plants, thirteen per cent. of zinc oxide was found; in other plants, from ·3 per cent. to 3·3 per cent.

From the investigations of Baumann,[2] insoluble zinc salts in the soil are harmless to plants. All plants excepting the Coniferæ speedily die in a solution containing 10 mg. zinc to the litre, though traces of zinc in solution are harmless.

The specific action of zinc on the vegetable organism consists in a destruction of the chlorophyl coloring matter and a consequent stoppage of the whole process of assimilation.

Experiments[3] on maize, oats, buckwheat, show that arsenic attacks the protoplasm of the cell and destroys the power of osmose by the roots.

Sulphates occur in the cell sap of organs where chemical changes are rapidly taking place, and are doubtless formed in connection with the decomposition of proteids. Phosphorus occurs in actively growing cells in the most various plants. It has been found present in the green coloring matter of the leaves and is always found in relation with living protoplasm. Schumacher[4] holds, that the chief work of the alkaline phosphates is the acceleration of the diffusion of these difficultly diffusible albuminoids.

Calcium is especially abundant in the leaves of green trees and it cannot be replaced in the food of green leaves by any other metal. It can be replaced by strontium,[5] barium, or magnesium in the food of certain Fungi. Magnesium[6] resembles lime in many

[1] A. Braun and Risse (Sachs; *Exp. Physiologie*, 153).

[2] *Landw. Versuchs-Stat.*, *xxxi*, 1-53 (*Jour. Chem. Soc.*, 1884, p. 1408.)

[3] F. Nobbe and others. *Landw. Versuchs-Stat.*, *xxx*, 381–422. (*Jour. Chem. Soc.*, 1884, p. 1409.)

[4] *Physik der Pflanze*, p. 128.

[5] Naegeli.

[6] R. Hornberger and E. V. Raumer; *Bied. Centr. Bl.*, 1882, 837–844 (*Jour. Chem. Soc.*, 1883, p. 491.)

points, but is present in larger quantity in the stem and grain, and not in the leaves of the maize plant.

Iron is found to be essential to green plants only. If a seedling be cultivated by water culture in a fluid containing no iron, the leaves will become pale until at length they are nearly white, but on the addition of a small quantity of iron to the solution, or if the white leaves are painted with a dilute iron solution, they will very shortly become green. It plays an important part in the formation of the green coloring matter, though it does not enter into its chemical composition.

"Buckwheat,[1] barley and oats do not flourish when grown in solutions containing no chlorides, and as in these plants the chlorophyl corpuscles become overfilled with starch grains, it was thought that this element was of importance in connection with the translocation of carbo-hydrates."

Sodium[2] has been used in water culture to replace potassium, but the plants deprived of potash did not develop.

Manganese is abundant in the ash of *Trapa natans*. I also found it in the different portions of *Yucca angustifolia*.[3]

Iodine and bromine are found in marine *Algæ* and in minute quantity in some plants grown far from the sea.

Silica is found in the form of soluble or insoluble silicic acid. It occurs principally in the cell wall, but it has been found in the cell sap of a plant (*Equisetum hiemale*[4]), and certain cells in the pseudo bulbs of epiphytic Orchids[5] contain each a plate of silica.

Experiments have shown that the absorption of silicic[6] acid greatly assists the assimilation of other plant foods, and that plants to which it is supplied show a decidedly more healthy development of grain and straw than others not so treated. Silica is doubtless of mechanical use, giving firmness and rigidity to plant

[1] Vines; Cambridge Edition, p. 136. Also, Beyer; *Landw. Versuchs-Stat., xi.* Leydhecker; *ibid, viii.*

[2] Salm-Horstmar; Knop and Schreber.

[3] *Yucca Angustifolia.* Helen C. DeS. Abbott, *Trans. Am. Philos. Soc.*, Dec., 18, 1885.

[4] Lange; *Ber. d. deutsch. chem. Ges., xi.*

[5] Pfitzer; *Flora*, 1877.

[6] C. Kreuzhage and E. Wolff; *Landw. Versuchs.-Stat., xxx*, 161–198. (*Jour. Chem. Soc.*, 1884, p. 1112.)

tissues; though the real cause of "laying" of crops has been found to be due to the imperfect development of the tissue and not to an insufficient supply of silica.

The percentage of ash constituents in plants varies, but the quantity is sufficient to be a very important factor in the consideration of chemical forms of plants.

I have already said that the albuminous cell contents, called protoplasm, are always present in the living cells of plants. The introduction into the cell of the gases, water, and inorganic substances goes to the direct formation of this colloidal body, or assists in it.

It has been stated that the soil, water, and atmosphere supply the food of all plants. It would be of interest to dwell upon the processes of assimilation, and the chemical changes that go on within the living plant, if our time would allow. It may be mentioned that nowhere in any department of chemistry have our former views been more modified than in the physiological chemistry of the vegetable cell during the last three years.

For example, I may say, that, at least in some plants, nascent starch passes in a soluble form from cell to cell by osmosis without conversion into sugar, as was formerly held.

Sugar in some plants may be regarded as a waste product, resulting from the breaking down of more complex substances, of no further service in the development of the plant.

Sorghum[1] cane, at the time of the maturing of the seed and the full growth of the plant, contains the largest percentage of sugar, and this sugar appears to be really a waste product.

The classification[2] *of Plastic and Waste Products*, in Vines's late *Physiology*, cannot be accepted as final, since many changes in plant chemistry have resulted since 1882—the date of his chemical bibliography.

It may be generally said that the proteids or albuminoid substances are formed in the cell from a simple carbo-hydrate and some nitrogenous body, probably an amide.

The inorganic acids supply sulphur and other substances necessary to enter into combination with the proteid, or act mechanically by removing waste material.

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[1] H. W. Wiley; *Botanical Gazette*, 1887.

[2] Cambridge Edition, 1886.

The function of chlorophyl may be briefly stated:[1] It absorbs certain rays of light, and thus enables the protoplasm of the cell to avail itself of the radiant energy of the sun's rays for the construction of organic substances from carbon-dioxide and water.

Plants which are grown in the dark, or at low temperature, are usually of a yellow color. Such plants are said to be etiolated. There is reason to think that this yellow substance, etiolin, is an intermediate substance in the formation of chlorophyl, for if it is exposed to light it is converted into a green color; these complex coloring matters are probably derivatives of protoplasm.

The autumnal change of leaves is owing to a third coloring matter, called xanthophyl; in many cases, the leaves also contain a red coloring matter, erythrophyl.

The importance of chlorophyl in the plant will be admitted when it is said that the absorption of carbon-dioxide, the evolution of oxygen, and the formation of many organic substances are effected solely by chlorophyl corpuscles.

The organic acids occur in plants free and also in combination with bases. It is to the presence of these bodies that the acid reaction of plant tissues is due. Some organic acids are assimilated by plants; the turgidity of cells is to be ascribed to their presence, and the acid sap in root hairs renders possible the solution and absorption of mineral substances insoluble in water.

The primary function of the resins[2] of Coniferæ and analogous juices of other plants is to render service in cases of injury, and, by covering the wound with a protecting coating, to favor its healing.

During my studies on the *Yucca*[3], resins and saponin were separated from each part of the plant. Experiments were made to determine the emulsive power of saponin on resins. It was found that aqueous solutions of saponin were able to emulsify many classes of resins, and in my paper it was pointed out that saponin may serve mechanical purposes in the plant as well as those of nutrition.

The succession of plants from the lower to the higher forms

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[1] Cambridge Edition, p. 157.

[2] H. De Vries; *Chem. Centr. Bl.* **3**, *xiii*, 565. (*Jour. Chem. Soc.*, 1883, p. 365.)

[3] *Trans. Am. Phil. Soc.*, Dec., 1885.

will be reviewed superficially, and chemical compounds noted where they appear.

When the germinating spores of the Fungi, *myxomycetes*, rupture their walls and become masses of naked protoplasm, they are known as plasmodia. The plasmodium *Æthalium septicum* occurs in moist places, on heaps of tan or decaying barks. It is a soft, gelatinous mass of yellowish color, sometimes measuring several inches in length.

The plasmodium[1] has been chemically analyzed, though not in a state of absolute purity. The table of Reinke and Rodewold gives an idea of its proximate constitution.

Many of the constituents given are always present in the living cells of higher plants. It cannot be too emphatically stated that where "biotic" force is manifested, these colloidal or albuminous compounds are found.

The simplest form of plant life is an undifferentiated individual, all of its functions being performed indifferently by all parts of its protoplasm.

The chemical basis of plasmodium is almost entirely composed of complex albuminous substances, and correlated with this structureless body are other compounds derived from them. Aside from the chemical substances which are always present in living matter, and are essential properties of protoplasm, we find no other compounds. In the higher organisms, where these functions are not performed indifferently, specialization of tissues is accompanied by many other kinds of bodies.

The Algæ are a stage higher in the evolutionary scale than the undifferentiated non-cellular plasmodium. The simple *Alga protococcus*[2] may be regarded as a simple cell. All higher plants are masses of cells, varying in form, function and chemical composition.

A typical living cell may be described as composed of a cell wall and contents. The cell wall is a firm, elastic membrane closed on all sides, and consists mainly of cellulose, water, and inorganic constituents. The contents consists of a semi-fluid colloidal substance, lying in contact with the inner surface of the membrane,

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[1] *Studien über das Protoplasm*, 1881.

[2] Vines, p. 1. Rostafinski; *Mem. de la Soc. des Sc. Nat. de Cherbourg*, 1875. Strasburger; *Zeitschr.*, XII, 1878.

and like it closed on all sides. This always is composed of albuminous substances. In the higher plants, at least, a nucleus occurs embedded in it, a watery liquid holding salts and saccharine substances in solution, fills the space called the vacuole enclosed by the protoplasm.

These simple plants may be seen as actively moving cells, or as non-motile cells. The former consist of a minute mass of protoplasm, granular and mostly colored green, but clear and colorless at the more pointed end, and where it is prolonged into two delicate filaments called cilia. After moving actively for a time they come to rest, acquire a spherical form and invest themselves with a firm membrane of cellulose. This firm, outer membrane of the *Protococcus* accompanies a higher differentiation of tissue and localization of function than is found in the plasmodium.

Hæatococcus and plasmodium come under the classes Algæ and Fungi of the Thallothyta group. The division[1] of this group into two classes is based upon the presence of chlorophyl in Algæ and its absence in Fungi. Gelatinous starch is found in the Algæ; the Fungi contain a starchy substance called glycogen, which also occurs in the liver and muscles of animals. Structureless bodies, as *æthalium*, contain no true sugar. Stratified starch[2] first appears in the Phanerogams. Alkaloids have been found in Fungi, and owe their presence doubtless to the richness of these plants in nitrogenous bodies.

In addition to the green coloring matter in Algæ are found other coloring matters.[3] The nature[4] of these coloring matters is usually the same through whole families, which also resemble each other in their modes of reproduction.

In form, the Algæ differ greatly from filaments or masses of cells; they live in the water and cover damp surfaces of rocks and wood. In these they are remarkable for their ramifications and colors and grow to a gigantic size.

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[1] *Botany;* Prantl and Vines. London, 1886, p. 110.

[2] For the literature of Starch, see p. 115, *Die Pflanzenstoffe*, von Hilger and Husemann.

[3] *Kützing; Arch. Pharm. xli*, 38. Kraus and Millardet; *Bul. Soc. Sciences. Nat.*, Strasbourg, 1868, 22. Sorby; *Jour. Lin. Soc. xv*, 34. J. Reinke; *Jahrb. Wissenscht. Botan.*, *x*, B. 399. Phipson; *Phar. Jour. Trans. clxii*, 479.

[4] Prantl and Vines, p. 111.

The physiological functions of Algæ and Fungi depend upon their chemical differences.

These facts have been offered, simple as they are, as striking examples of chemical and structural opposition.

The Fungi include very simple organisms, as well as others of tolerably high development, of most varied form from the simple bacillus and yeast to the truffle, lichens, and mushrooms.

The cell membrane of this class contains no pure cellulose, but a modification called fungus cellulose. The membrane also contains an amyloid substance, amylomycin.[1] Many of the chemical constituents found in the entire class are given in *Die Pflanzenstoffe*.[2]

Under the *Schizomycetes* to which the *Micrococcus* and *Bacterium*[3] belong are found minute organisms differing much in form and in the coloring[4] matters they produce, as that causing the red color of mouldy bread.

The class of lichens[5] contains a number of different coloring substances, whose chemical composition has been examined. These substances are found separately in individuals differing in form. In the *Polyporus*[6] an acid has been found peculiar to it, as in many plants special compounds are found. In the Agariceæ the different kinds of vellum distinguish between species, and the color of the conidia is also of differential importance. In all cases of distinct characteristic habits of reproduction and form, one or more different chemical compounds is found.

In the next group of the Musiceæ, or mosses, is an absence of some chemical compounds that were characteristic of the classes

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[1] L. Crie; *Compt. Rend.*, *lxxxviii*, 759 and 985. J. de Seynes, 820, 1043.

[2] Page 279.

[3] M. Nencki and F. Schaffer. N. Sieher; *Jour. Pract. Chem.*, 23, 412.

[4] E. Klein; *Quar. Jour. Micros. Science*, 1875, 381. O. Helm; *Arch. Pharm.*, 1875, 19–24. G. Gugini: *Gaz. Chem.*, 7, 4. W. Thörner; *Bul. Ber.*, *xi*, 533.

[5] *Handbook of Dyeing*. By W. Crookes, London, 1874, p. 367. Schunck; *Ann. Chem. Pharm.*, *41*, 157; *54*, 261; *61*, 72; *61*, 64; *61*, 78. Rochelder and Heldt, *Ibid*, *48*, 2; *48*, 9. Stenhouse, *Ibid*, *68*, 57; *68*, 72; *68*, 97, 104; *125*, 353. See also researches of Strecker; O. Hesse; Reymann; Liebermann; Lamparter; Knop and Schnedermann.

[6] Stahlschmidt.

just described. Many of the albuminous substances are present. Starch[1] is found often in large quantities, and also oily fats, which are contained in the oil bodies of the liverworts; wax,[2] organic acids, including aconitic acid, and tannin which is found for the first time at this evolutionary stage of the plant kingdom.

The vascular Cryptogams are especially characterized by their mineral composition.[3] The ash is extraordinarily rich in silicic acid and alumina.

Equisetum,[4]	silicic acid	60 per cent.
Aspidium, ...	" "	13 " "
Asplenium, ...	" "	35 " "
Osmunda, ...	" "	53 " "
Lycopodium,[5]	" "	14 " "
"	alumina	26 to 27 " "
"	manganese	2 to 2·5 " "

These various plants contain acids and compounds peculiar to themselves.

As we ascend in the plant scale, we reach the Phanerogams. These plants are characterized by the production of true seeds, and many chemical compounds not found in lower plants.

It will be convenient in speaking of these higher groups, to follow M. Heckel's[6] scheme of plant evolution. All these plants are grouped under three main divisions: apetalous, monocotyledonous, and dicotyledonous, and these main divisions are further subdivided.

It will be observed that these three main parallel columns are divided into three general horizontal planes.

On plane 1, are all plants of simplicity of floral elements, or parts; for example, the black walnut with the simple flower contained in a catkin.

On plane 2, plants which have a multiplicity of floral elements, as the many petals and stamens of the rose; and finally, the higher

[1] E. Treffner; *Inaugur. Diss. Dorpat*, 1880.

[2] W. Pfeffer; *Flora*, 1874.

[3] *Die Pflanzenstoffe*, p. 323. W. Lange; *Bul. Ber.*, *xi*, 822.

[4] *Ann. Chim. Phys.*, *41*, 62, 208; *Ann. Chim. Pharm.*, *77*, 295.

[5] Flückiger; *Pharmakognosie*. Kamp; *Ann. Chim. Pharm.*, *100*, 300.

[6] *Revue Scientifique*, 13 Mars, 1886.

plants, the Orchids among the monocotyledons and the Compositæ among the dicotyledonous plants, come under the third division of condensation of floral elements.

It will be impossible to take up in order for chemical consideration all these groups, and I shall restrict myself to pointing out the occurrence of certain constituents.

I desire now to call attention to chemical groups under the apetalous plants having simplicity of floral elements.

Cassuarina equisetifolia[1] possibly contains tannin, since it is used for curing hides. The bark contains a dye. It is said to resemble *Equisetum*[2] in appearance, and in this latter plant, a yellow dye is found.

The *Myrica*[3] contains ethereal oil, wax, resin, balsam, in all parts of the plant. The root contains in addition fats, tannin and starch, also myricinic acid.

In the willow and poplar,[4] a crystalline, bitter substance, salicin or populin, is found. This may be considered as the first appearance of a real glucoside, if tannin be excluded from the list.

The oak, walnut, beech, alder, and birch contain tannin in large quantities; in the case of the oak ten to twelve per cent. Oak galls yield as much as seventy per cent.[5]

The numerous genera of pine and fir trees are remarkable for ethereal oil, resin, and camphor.

The plane[6] trees contain caoutchouc and gum; peppers,[7] ethereal oils, alkaloids, piperin, white resin and malic acid. *Datisca cannabina*[8] contains a coloring matter and another substance peculiar to itself, datiscin, a kind of starch, or allied to the glucosides.

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[1] *Dictionary of Economic Plants.* By J. Smith. London, 1882, p. 294.

[2] *Ibid*, p. 160. *Pharmakognosie des Pflanzenreichs*, Wittstein, p. 736. *Ann. Chem. Pharm.*, 77, 295.

[3] Rabenhorst; *Repert. Pharm.*, *lx*, 214. Moore; *Chem. Centralbl.*, 1862, 779, Dana.

[4] Johansen; *Arch. Pharm.*, **3**, *ix*, 210. *Ibid*, **3**, *ix*, 103. Bente; *Berl. Ber.*, *viii*, 476. Braconnot; *Ann. Chim. Phys.*, **2**, *44*, 296.

[5] Wittstein; *Pharm. des Pflanzenreichs*, p. 249.

[6] John; *Ibid*, p. 651.

[7] Dulong, Oersted, Lucas, Poutet; *Ibid*, p. 640.

[8] Braconnot; *Ann. Chim. Phys.*, **2**, *3*, 277. Stenhouse; *Ann. Chim. Pharm.*, *198*, 166.

Upon the same evolutionary plane among the monocotyledons, the dates and palms[1] contain in large quantities special starches, and this is in harmony with the principles of the theory. Alkaloids and glucosides have not yet been discovered in them.

Other monocotyledonous groups with simplicity of floral elements, such as the Typhaceæ, contain large quantities of starch; in the case of *Typha latifolia*,[2] 12·5 per cent., and 1·5 per cent. gum. In the pollen of this same plant, 2·08 per cent. starch has been found.

Under the dicotyledonous groups, there are no plants with simplicity of floral elements.

Returning, now, to apetalous plants of multiplicity and simplification of floral elements, we find that the Urticaceæ[3] contain free formic acid; the hemp[4] contains alkaloids; the hop,[5] ethereal oil and resin; the rhubarb,[6] crysophonic acid, and the begonias,[7] chicarin and lapacho dyes. The highest apetalous plants contain camphors and oils. The highest of the monocotyledons contain a mucilage and oils, and the highest dicotyledons contain oils and special acids.

The trees yielding common camphor and Borneol are from genera of the Lauraceæ family; also sassafras camphor is from the same family. Small quantities of Stereoptenes are widely distributed through the plant kingdom.

The Gramineæ, or grasses, are especially characterized by the large quantities of sugar and silica they contain. The ash of the rice hull, for example, contains ninety-eight per cent. silica.

The Ranunculaceæ contain many plants which yield alkaloids, as *Hydrastia canadensis*, or Indian hemp, *Helleborus*, *Delphinum*, *Aconitum*, and the alkaloid berberine has been obtained from genera of this family.

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[1] *Pflanzenstoffe*, p. 412.

[2] Lecocq; Braconnot; *Pharmacog. Pflan.*, p. 693.

[3] Gorup-Besanez.

[4] Siebold and Brodbury; *Phar. Jour. Trans.* **3**, 590, 1881, 326.

[5] Wagner; *Jour. Prakt. Chem.*, *58*, 352. E. Peters, v. Gohren; *Jahresb. Agric.*, *viii*, 114; *ix*, 105; *v*, 58. *Am. Jour. Pharm.* **4**, 49.

[6] Dragendorff; *Pharm. Zeitschr. Russ.*, *xvii*, 65–97.

[7] Boussingault; *Ann. Chim. Phys.* **2**, *27*, 315. Erdmann; *Jour. Pract. Chem.* *71*, 198.

The alkaloid[1] furnishing families belong, with few exceptions, to the dicotyledons. The Colchiceæ, from which is obtained veratrine, form an exception among the monocotyledons. The alkaloids of the fungus have already been noted.

[2] Among the greater number of plant families, no alkaloids have been found. In the Labiatæ none has been discovered, nor in the Compositæ among the highest plants.

One alkaloid is found in many genera of the Loganiaceæ Berberine in genera of the Berberidaceæ, Ranunculaceæ, Menispermaceæ, Rutaceæ, Papaveraceæ, Anonaceæ.

Waxes are widely distributed in plants. They occur in quantities in some closely related families.

Ethereal oils occur in many families, in the bark, root, wood, leaf, flower and fruit; particularly in Myrtaceæ, Laurineæ, Cyperaceæ, Crucifereæ, Aurantiaceæ, Labiatæ and Umbelliferæ.

Resins are found in most of the higher plants. Tropical plants are richer in resins than those of cold climates.

Chemical resemblance between groups, as indicating morphological relations has been well shown. For example; the similarity[3] of the viscid juices, and a like taste and smell among Cactaceæ and Portulaceæ, indicate a closer relationship between these two orders than botanical classification would perhaps allow. This fact was corroborated by the discovery of irritable stamens in *Portulaca* and *Opuntia*, and other genera of Cactaceæ.

Darwin[4] states, that in the Compositæ the ray florets are more poisonous than the disc florets in the ratio of about 3 to 2.

Comparing the Cycadeæ and Palmæ, the former are differently placed by different botanists, but the general resemblance is remarkable, and they both yield sago.

Chemical constituents of plants are found in varying quantities during stated periods of the year. Certain compounds present at one stage of growth are absent at another. Many facts could be brought forward to show the different chemical composition of plants in different stages of growth. The *Thuja occidentalis*,[5] in

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[1] *Die Pflanzenstoffe*, p. 21.

[2] *Ibid.*

[3] Meehan; *Proc. Acad. Nat. Sciences.*

[4] Different forms of flowers on plants of the same species. Introduction.

[5] Meehan; *Proc. Acad. Nat. Sciences.*

the juvenescent and adult form, offers an example where morphological and chemical differences go hand in hand. Analyses of this plant under both conditions show a striking difference.

Different parts of plants may contain distinct chemical compounds, and the comparative chemical study of plant orders comprises the analysis of all parts of plants of different species.

For example; four portions of the *Yucca angustifolia*[1] were examined chemically; the bark and wood of the root and the base and blades of the leaves. Fixed oils were separated from each part These were not identical; two were fluid at ordinary temperature, and two were solid. Their melting and solidifying points were not the same.

This difference in the physical character and chemical reaction of these fixed oils may be due to the presence of free fatty acid and glycerides in varying proportions in the four parts of the plants. It is of interest to note that, in the subterranean part of the *Yucca*, the oil extracted from the bark is solid at the ordinary temperature: from the wood it was of a less solid consistency; while the yellow base of the leaf contained an oil quite soft, and in the green leaf the oil is almost fluid.

Two new resins were extracted from the yellow and green parts of the leaf. It was proposed to name them *yuccal* and *pyrophœal*. An examination of the contents of each extract showed a different quantitative and qualitative result.

Saponin was found in all parts of the plant.

Many of the above facts have been collected from the investigations of others. I have introduced these statements, selected from a mass of material, as evidences in favor of the view stated at the beginning of this paper.[2] My own study has been directed towards the discovery of saponin in those plants where it was presumably to be found. The practical use of this theory in plant analysis will lead the chemist at once to a search for those compounds which morphology shows are probably present.

I have discovered saponin in all parts of the *Yucca angustifolia*

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[1] H. C. DeS. Abbott; *Trans. Amer. Philos. Soc.*, 1886.

[2] For further facts confirming this theory, see "Comparative chemistry of Higher and Lower Plants." By H. C. DeS. Abbott. *Amer. Naturalist*, August, 1887.

in the *Y. filimentosa* and *Y. gloriosa*, in several species of Agavæ, and in plants belonging to the Leguminosæ family.

The list[1] of plants in which saponin has been discovered is given in the note. All these plants are contained in the middle plane of Heckel's scheme. No plants containing saponin have been found among apetalous groups. No plants have been found containing saponin among the lower monocotyledons.

The plane of saponin passes from the Liliaceæ and allied groups to the rosales and higher dicotyledons.

Saponin belongs to a class of substances called glucosides. Under the action of dilute acids, it is split up into two substances, glucose and sopogenin. The chemical nature of this substance is not thoroughly understood. The commercial[2] product is probably a mixture of several substances.

This complexity of chemical composition of saponin is admirably adapted for the nutrition of the plant, and it is associated with the corresponding complexity of the morphological elements of the plant's organs According to M. Perrey[3], it seems that the power of a plant to direct the distribution of its carbon, hydrogen, and oxygen to form complex glucosides is indicative of its higher functions and developments.

The solvent action of saponin on resins has been already discussed. Saponin likewise acts as a solvent upon barium[4] sulphate and calcium[5] oxalate, and as a solvent of insoluble or slightly soluble salts would assist the plant in obtaining food, otherwise difficult of access.

Saponin is found in Endogens and Exogens. The line dividing these two groups is not always clearly defined. Statements pointing to this are found in the works of Haeckel, Bentham, and others.

Smilax belongs to a transition class, partaking somewhat of the

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[1] Different genera and species of the following: Ranunculaceæ, Berberidaceæ, Carophyllaceæ, Polygalaceæ, Bromeliaceæ, Liliaceæ, Smilaceæ, Yuccas, Amaryllideæ, Leguminosæ, Primulaceæ, Rosaceæ, Sapindaceæ, Sapotaceæ.

[2] Kobert; *Chem. Ztg.*

[3] *Compt. Rend., xciv*, p. 1124.

[4] *Bul. de la Soc. Chim.*

[5] "Yucca angus." *Trans. Am. Philos. Soc.*, Dec., 1885.

nature of Endogen and of Exogen. It is worthy of note that this intermediate group of the sarsaparillas should contain saponin.

It is a significant fact that all the groups above named containing saponin belong to Heckel's middle division.

It may be suggested that saponin is thus a constructive element in developing the plant from the multiplicity of floral elements to the cephalization of those organs.

It has been observed that the composite occurs where the materials for growth are supplied in greatest abundance, and the more simple forms arise where sources of nutrition are remote. We may gather from this fact that the simpler organs of plants low in the evolutionary scale contain simpler non-nitrogenous chemical compounds for their nutrition.

The presence of saponin seems essential to the life of the plant where it is found, and it is an indispensable principle in the progression of certain lines of plants, passing from their lower to their higher stages.

Saponin is invariably absent where the floral elements are simple; it is invariably absent where the floral elements are condensed to their greatest extent. Its position is plainly that of a factor in the great middle realm of vegetable life, where the elements of the individual are striving to condense, and thus increase their physiological action and the economy of parts.

It may be suggested as a line of research to study what are the conditions which control the synthesis and gradual formation of saponin in plants. The simpler compounds of which this complex substance is built up, if located as compounds of lower plants, would indicate the lines of progression from the lower to the saponin groups.

In my paper[1] read in Buffalo at the last meeting of the American Association for the Advancement of Science, various suggestions were offered why chemical compounds should be used as a means of botanical classification.

The botanical classifications based upon morphology are so frequently unsatisfactory, that efforts in some directions have been made to introduce other methods.[2]

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[1] *Botanical Gazette*, October, 1886.

[2] Borodin; *Pharm. Jour. Trans.*, *xvi*, 369. Pax. Firemy; *Ann. Sci. Nat. xiii.*

There has been comparatively little study of the chemical principles of plants from a purely botanical view. It promises to become a new field of research.

The Leguminosæ are conspicuous as furnishing us with important dyes, *e. g.*, indigo, logwood, catechin. The former is obtained principally from different species of the genus *Indigofera*, and logwood from the *Hæmatoxylon* and *Saraca indica*.

The discovery[1] of hæmatoxylin in the *Saraca indica* illustrates very well how this plant in its chemical, as well as botanical, character is related to the *Hæmatoxylon campechianum*; also, I found a substance like catechin in the *Saraca*. This compound is found in the *Acacias*, to which class *Saraca* is related by its chemical position as well as botanically. Saponin is found in both of these plants as well as in many other plants of the Leguminosæ. The Leguminosæ come under the middle plane or multiplicity of floral elements, and the presence of saponin in these plants was to be expected.

From many of the facts above stated, it may be inferred that the chemical compounds of plants do not occur at random. Each stage of growth and development has its own particular chemistry.

It is said that many of the constituents found in plants are the result of destructive metabolism, and are of no further use in the plant's economy. This subject is by no means settled, and even should we be forced to accept that ground, it is a significant fact that certain cells, tissues or organs peculiar to a plant, secrete or excrete chemical compounds peculiar to them, which are to be found in one family, or in species, closely allied to it.

It is a fact that the chemical compounds are there, no matter why or whence they came. They will serve our purposes of study and classification.

The result of experiment shows that the presence of certain compounds is essential to the vigor and development of all plants and particular compounds to the development of certain plants. Plant chemistry and morphology are related. Future investigations will demonstrate this relation.

In general terms, we may say that amides and carbo-hydrates are utilized in the manufacture of proteids. Organic acids cause a turgescence of cells. Glucosides may be a form of reserve food material.

[1] H. C. DeS. Abbott, *Proc. Acad. Nat. Sciences*, Nov. 30, 1886.

Resins and waxes may serve only as protection to the surfaces of plants; coloring matters, as screens to shut off or admit certain of the sun's rays; but we are still far from penetrating the mystery of life.

A simple plant does what animals more highly endowed cannot do. From simplest substances they manufacture the most complex. We owe our existence to plants, as they do theirs to the air and soil.

The elements carbon, oxygen, hydrogen, and nitrogen pass through a cycle of changes from simple inorganic substances to the complex compounds of the living cell. Upon the decomposition of these bodies the elements return to their original state. During this transition those properties of protoplasm which were mentioned at the beginning, in turn, follow their path. From germination to death this course appears like a crescent, the other half of the circle closed from view. Where chemistry begins and ends it is difficult to say.

On ANEMOMETERS.

By G. A. Hagemann, Candidatus Polytech.

[*Translated by G. E. Curtis, from the "Annuaire météorologique" of the Danish Meteorological Institute, Copenhagen, 1877.*]

Introduction.—As the Hagemann anemometer has attracted some attention, and is easily obtained by purchase of the maker, Nyrop, of Copenhagen, and as the original memoir describing it is rather rare, I have, in compliance with several requests, suggested to the Franklin Institute, the propriety of publishing the following translation.

It is evident that Dr. Hagemann's preliminary investigation needs further development before the value of the instrument can be considered to be finally established. For measuring severe gusts and high wind velocities, an anemometer which has a minimum inertia of its own moving parts is very desirable, and this seems to be obtainable through the application of the principle of suction.

Cleveland Abbe.

A series of experiments upon the drafts of chimneys, for which I used a gauge constructed for the purpose, drew my attention to the fact that the draft up the chimney depends upon the force of the wind, so that each gust of air, no matter how feeble, that grazed the summit of the chimney, could be perceived in the apparatus for measuring the draft. Thus occurred the idea of utilizing the instrument as an anemometer, and I think I have established by the following experiments, its applicability to the simple and relatively very exact indication of the force of the wind, and thereby to the determination of the velocity.

The apparatus, as shown in *Fig. 3*, is substantially as follows:

In a reservoir, *a*, filled with water up to the level marked *l*, there is suspended by a wire or silk-thread a thin metallic bell, *b*; the upper end of the wire is fastened to a finely-tempered spring. A slit cut in the tube, containing the wire and spring, shows at *e* a small needle attached to the wire, whose motion is read off on a divided scale, *k*.

If now the metal-bell be given a diameter of 0·1128 m., or a section of 100 square centimetres, a suction in the tube *c*, whose top is above the water, equivalent in amount to one millimetre of water pressure, will produce a tension of ten grammes on the spring, which latter will be stretched thereby.

By choosing a spring of suitable force, the needle can easily be made to move ten millimetres for a pressure of ten grammes, and

thus the suction, as indicated on the scale, will be amplified ten times. The use of wheel-work admits of converting the original rectilinear motion into circular motion, and of amplifying still more the indications. If instead of suction, we wish to measure pressure, it is only necessary to load the bell, *b*, so as to make it sink, and the intensity of the wind-pressure can then be measured by the height to which the bell is raised, when the air in the tube *c* is compressed.

As a receiver of the wind, I have used a Pitot tube, *i. e.*, a tube with its aperture facing the wind, of 6 mm. interior diameter and with nicely sharpened edge, and also the tube designed by Captain Magius, of Copenhagen. The latter is simply a vertical tube, acting like a chimney, across whose top, also with sharpened edge, the wind blows at right angles to the axis of the tube.

In order to produce the currents of air requisite in these experiments, an apparatus was used represented in *Fig. 4*. The reservoir *A*, furnished with a grating *a*..... *a* is constantly fed with compressed air by a fan worked by hand. The pressure is such as the experiment requires. A manometer, *e*, is so placed that the person working the fan can constantly follow with his eye the variations of pressure in the reservoir *A*. This latter contains an orifice *d*, of 9·5 cm. interior diameter that can be fitted with tubes of different diameters. On the Table *D* are placed the various receivers, connected by rubber tubes with the apparatus, *g*, for measuring pressure or suction.

After having compared the gauges, and having found them to agree within a limit of error not exceeding 0·1 mm., I fixed a Pitot tube, 6 mm. aperture, facing a jet of air which emerged from *A*

through a round orifice 1·7 cm. in diameter. It then became manifest that the Pitot tube, as indicated by the manometers, *always* gave a pressure identical with the statical pressure in the reservoir A, when the distance of the tube to the orifice of escape did not exceed 5 cm. Experiments were made with pressures varying from 0 to 100 mm. of water and gave results agreeing perfectly.

From Weisbach's *Mechanik*, the velocity, v, of a current of air passing through an orifice in a thin plate is,

$$v = 396 \sqrt{(1 + \delta t) \frac{h'}{b + h'}} \text{ metres,}$$

where h' is the pressure in the reservoir expressed in millimetres of mercury.

Since the Pitot tube indicates a pressure precisely equal to that which forces the air to flow with the velocity v, the above formula ought also to indicate the velocity of a current of air producing an effect h' in the gauge attached to the Pitot tube.

As, moreover, the temperature, t, is the same in the whole mass of air in motion, and as h' is always a very small quantity compared with $b = 760$ mm., we can simplify the formula and substitute the approximation:

$$v = 396 \sqrt{\frac{h}{760 \times 13{\cdot}598}} = 3{\cdot}9 \sqrt{h} \text{ metres,}$$

where h is the pressure in millimetres of water, indicated by the manometer.

The diminution of pressure indicated by the Pitot tube, when its axis is oblique to the direction of the wind has been made the subject of observation and my results are contained in the following table.

TABLE I.

Distance from d, 30 cm. Diameter of d, 6 cm. Pressure in A, 10 mm.

Angle.	*Pressure in Pitot Tube.* mm.
0	6·1
10	6·1
20	6·0
30	5·75

The variations are so small that, up to an angle of 30° between

the direction of the wind and the axis of the tube, they do not exceed a few per cent.

The use of the Pitot tube, then, makes possible the construction of an anemometer that will operate with simplicity and precision; farther on, after having mentioned some difficulties that anemometers of this kind present, I will indicate more in detail the best method of construction.

Before beginning a review of my experiments made with the Magius tube, it will not be out of the way to examine more closely the current of air which emerges from an orifice in a thin plate, and to review the following experiments.

TABLE II.

Pressure in A, 8 mm.

Distance from d.	*Pressure in Pitot Tube.*	*Distance from d.*	*Pressure in Pitot Tube.*
cm.	mm.	cm.	mm.
0.25	8·	9·	5·5
1·	8·	10·	4·45
2·	8·	15·	2·1
4·	8·	21·5	1·4
5·	8·	26·	1·1
6·	7·5	30·	0·75
7·	6·9	41·6	0·6
8·	6·35		

Whence it results in detail that for a distance from the orifice less than 5·5 cm., the latter having a diameter of 1·7 cm., a Pitot of 7 mm. diameter indicates the same pressure at the centre of the current of air as in the interior of the reservoir *A*. But if this distance be exceeded, the pressure begins to diminish rapidly, because the jet of air drags along the surrounding air in its course, and so loses velocity. It is only at a distance of 40 cm. that the mass of air seems to flow with a pretty uniform motion. Further experiments will throw more light on the distribution of pressure in the air-current.

The vertical tubes proposed by Captain Magius have not yet, so far as I know, been subjected to precise investigation, and consequently it was necessary, as a preliminary step, to know just how far the size and shape of the orifice exerts an influence, and also at what limits the indications remain proportional to the wind

velocity. Such was the object of the experiments presented below:

TABLE III.

Distance from *d*, 6 cm. Diameter of *d*, 2 cm.

Pressure in A,	*Suction in Tubes of different Sizes and Shapes.*					
	7 mm.	6 mm.	4 mm.	2 mm.	1 mm.	4 mm.
mm.	mm.	mm.	mm.	mm.	mm.	mm.
1	0·4	0·4				0·4
2	0·7	0·7	0·7	0·6	0·5	0·7
3	1·1	1·1				
4	1·5	1.5	1·55	1·2	1·0	1·5
5	1·9	1·9				
6	2·3	2·4	2·4	1·8	1·5	2·4
7	2·9	2·9				
8	3·4	3·4	3·4	2·9	2·0	3·25

These experiments show that all the Magius tubes having an aperture of 7 to 4 mm., give results which agree very closely, and impress a certain stamp of continuity on the curve that is obtained by making the pressure in *A* an abscissa and the suction an ordinate. For very small capillary tubes, on the contrary, such is no longer the case. The energy of suction diminishes with the diameter, and there is no continuity in the indications. A cause, however, which contributes to this irregularity, is found in the fact that the experiments were not continued a sufficiently long time, as is apparent from the following series of experiments in which the first and third tubes had their edges sharpened, but the middle tube not.

TABLE IV.

Distance from *d*, 6·5 cm. Diameter of *d*, 8 cm. Pressure in *A*, 10 mm.

Duration of Experiment.	*Suction in Magius Tubes.*		
minute.	5 mm. diam.	1·25 mm. diam.	1·25 mm. diam.
0·5	5·25	2·0	2·0
1·0	6·1	3·5	3·4
1·5	6·3	4·25	4·25
2·0	6·4	4·7	5·0
3·0	6·4	4·9	5·5
4·0		5·0	5·7
5·0		5·1	5·75
6·0		5·1	5·75

A Magius tube, even of 5 mm. diameter, takes an appreciable

time to rarefy all the enclosed air, and consequently it is not surprising that the capillary tubes require still more time. The reason that these latter tubes do not come to indicate a suction as great as tubes of larger calibre ought assuredly to be found in the influence of the capillary walls on the air. The following result then obtains: Capillary tubes are poorer receivers of the wind, and ought to be employed only so far as they can be shown to be more suitable than larger tubes in keeping free from obstruction in all kinds of weather.

Magius tubes of large diameter give, suctions proportional to the velocity of the wind, at least up to 8 mm. of pressure in *A*.

Beyond that limit I have been obliged to content myself with using simple curved glass tubes as gauges, instead of the form of manometer previously described.

TABLE V.

Distance from *d*, 6 cm. Diameter of *d*, 2 cm.

Pressure in A.	*Suction in Magius Tubes.*			
	7 mm. diam.	7 mm. diam.	5 mm. diam.	mean.
7·		3·0		3·0
8·	3·4			3·4
11·5		5·0		5·0
16·		7.0		7·0
20·	7·5	9·0		8·25
30·	11·0		12·0	11·5
40·	14·0		17·0	15·5

In spite of the comparatively large uncertainty in these measurements, nevertheless, I venture to assume, that further experiments will show that the ratio is maintained at least up to 100 mm. of pressure in *A*, and perhaps even beyond that limit. The action of the Magius tube is to be explained as being the result of cohesion between the molecules of the air current, which touches the open end of the tube and those of the air contained in the tube.

That is the reason we ought to find in these tubes the total effect which corresponds to different velocities, so long as cohesion does not vanish, which never occurs until a perfect vacuum is reached. It is presumable, however, that the higher velocities demand an appreciable time for the suction to attain its full value, but I have not yet measured this time.

If then, relying on the experiments presented in Tables III and V, one should conclude that the velocity of the wind preserves a

definite ratio to the suction measured in the Magius tube, and consequently that it could be expressed by

$$v = 3{\cdot}9\sqrt{a\,h} \text{ metres},$$

he would be in error, because what we have really measured in these experiments is not the velocity of the current of air or the suction that the current is able to produce, but, on the contrary, *the difference between the suction and the pressure shown by the air-jet.* In order that a current of air shall open a way for itself in a mass of quiet air, it must do mechanical work, and consequently at every point must undergo a compression or exercise a pressure which is proportional to the work to be performed. It is this pressure which affects the indications of a Magius tube; if we contract the orifice of escapement, there is added to these causes a contraction of the air-jet. By changing the diameter of the orifice, and consequently the pressure of the jet, we obtain—

TABLE VI.

Distance from d, 6·5 cm. Diameter of d, 9·5 cm.

Pressure in A.	*Suction in Magius Tubes.*	*Pressure in A.*	*Suction in Magius Tubes.*
1	1·0	6	4·75
2	1·8	8	6·25
4	3·3	10	7·75

So long as the velocity of the air current is small, and consequently the pressure of the jet light, the Magius tubes indicate a suction almost equal to the pressure in the reservoir A, but in proportion as the velocity and, with it, the pressure of the jet increases, this very pressure reacts on the suction, but to a less degree than that observed in experiments III and V, because now the orifice is very much larger. We can now draw the conclusion that the Magius tube cannot afford a very exact measure of wind gusts, because such gusts behave in the same way with respect to surrounding air, as the air-jet in these experiments. These gusts must contain compressed air, which naturally renders them incapable of producing in the Magius tube a suction as great as it ought to be by reason of their velocity. The following experiment will set forth, in a most striking manner, the distribution of pressure in the jet:

TABLE VII.

Diameter of *d*, 1·7 cm. Pressures in *A*, 8 mm.

Distance from d.	*Pitot Tube*, 6 mm.	*Magius Tube*, 6 mm.	*Pressure in Jet.*
0·25	8·0	1·8	6·2
4·0	8·0	2·9	5·1
6·0	7·5	3·4	4·1
10·	4·5	2·9	1·6
17·	2·0	1·6	0·4
21·5	1·5	1·2	0.3
26·	1·1	1·0	0·1
30·	0·75	0·75	0·0
41·6	0·6	0·6	0·0

I have shown above that experiments III, V and VI cannot lead to the expression of the velocity of the wind measured in the Magius tube. The conditions of experiment are such as do not admit of obtaining empirically the true expression, because we cannot produce an artificial current of air in which there is no additional pressure. However, we can arrive at it approximately. As the tables show, the pressure of the jet must be less at the opening of large orifices than at that of small ones, because the Magius tubes indicate with the latter a larger suction If, then, we look for some law, according to which the size of the orifice exerts an influence on the suction, or on the diminution of pressure in the jet, we shall reach the desired result. The following experiment throws light on this point:

TABLE VIII.

Distance from *d*, 30 cm. Pressure in *A*, 10 mm.

Diameter of d.	*Pitot Tube*, 6 mm.	*Magius Tube*, 6 mm.
2·		1·0
4·2		3·25
6·		4·6
8·	6·6	5·75
9·5	6·75	6·35

If the squares of the diameters, *d*, be laid off on the axis of abscissas and the suctions be used as ordinates, we obtain a continuous curve. (*Fig. 5.*)

Just as this curve manifestly tends, with the increase of abscissas, to become parallel to the axis of abscissas, so we see it, in addition, approaching a portion of the curve generated in the same manner with the Pitot tube, and we cannot doubt that, by sufficiently increasing the abscissas, even up to the point where the air,

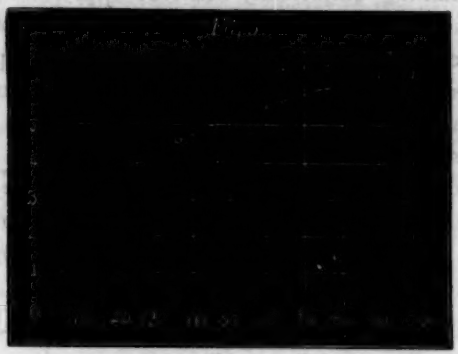
rushing through the orifice, constitutes a mass animated with a uniform motion, *we shall obtain, both from the Pitot tube and the Magius tube, indications of pressure in the first and of suction in the second, corresponding exactly to the pressure under which the air-current is expelled from the reservoir A.*

As experiments with natural and uniform air-currents have confirmed the correctness of this conclusion, the velocity of the wind, as measured with a Magius tube, will be expressed by the same formula as in the case of the Pitot tube, namely:

$$V = 3{\cdot}9\ \sqrt{h},$$

where h is the suction expressed in millimetres of water, indicated by the gauge.

When the air-current does not move normally to the orifice of the Magius tube, we shall no longer have, as one could suppose



in advance, the indication given by the whole velocity of the wind. In the following table are given the measurements obtained for different angular displacements.

TABLE X.

Distance from d, 6·5 cm. Diameter of d, 2 cm. Pressure in A, 8 mm.

Deviation of Tube from the Vertical.		*Magius Tube.*	
→			
<	>		
		mm.	mm.
6°		3·4	
	6°	3·4	
6°			3·1
10°			2·8
	10°		3·3
⊥			3·35

Distance from d, 30·0 cm. Diameter of d, 9·5 cm. Pressure in A, 10 mm.

Deviation of the Tube from the Vertical.	*Magius Tube.*
	mm.
⊥	6·5
6°	6·5
6°	6·5
12°	6·25
12°	6·25
15°	5·70
15°	5·40

Any small deviations from the vertical made by the tube are, from the above, insignificant. If, however, the angle amounts to 15°, the resulting effect assumes sensible proportions. We see also that it is preferable to give the tube a very sharp bevelled edge, and to admit only a very small thickness at the lips of the orifice.

If now we take a glance at all the preceding measurements, and the conclusions deduced therefrom, we arrive at the following results:

(1.) The Pitot tube can form the basis of a good, precise anemometer, which is only a very little affected by small deviations from parallelism with the direction of the wind.

(2.) The Magius tube, except with capillary diameters, constitutes a good receiver of the wind for constant velocities, but is not able to register accurately gusts of wind, because the latter are composed of compressed air. The Magius tube will not admit any great deviation from the vertical.

I have found these results fully justified by experiment with natural winds. So long as the wind blows uniformly, the Pitot and Magius tubes are on exactly the same footing, but as soon as there comes a gust, their agreement disappears, the two gauges then begin at once to indicate the change, but whilst the manometer connected with the Pitot tube rapidly attains its maximum, a noticeable time elapses before the apparatus, which measures the suction in the Magius tube, can keep pace with it, and it is only when the gust reaches the condition of a uniform wind of higher velocity that the Magius tube comes finally to give the same change as the Pitot tube. Many gusts are of so short duration that one can scarcely observe them by means of their feeble instantaneous

suction in the Magius tube, which, besides, is not at all a true measure of their velocity.

While for the reasons presented, the Magius tube gives as a general result too weak indications, yet there are two other factors which ought to be mentioned as tending partly to counter-balance this error; namely, the force of expansion of the air in the tube itself, when the latter is in any place having a temperature higher than that of the surrounding air, or when it is heated by the sun; second, the oscillations of the tube. The first source of error is common to both Pitot and Magius tubes, and it is easy enough to make a correction for it; but as to the latter, which is complicated in its action, it is hard to give any general rules. So far as I have been able to observe, it is not the oscillation that takes place in the direction of the wind which increases the suction, because its effect should cancel itself (that is why the oscillation has no perceptible effect in the case of the Pitot tube), but it is any oscillation that makes an angle with the direction of the wind. Suppose the wind sweeps over the upper open end of the tube, and suppose that the tube oscillates in the air, the effect should be the same, because it is the relative velocity which is the cause of the suction.

In order to estimate the amount of the error, I have used a Magius tube, 10 cm. long, set in a rubber collar, so as to be oscillated by a strong current of air and I found—

TABLE XI.

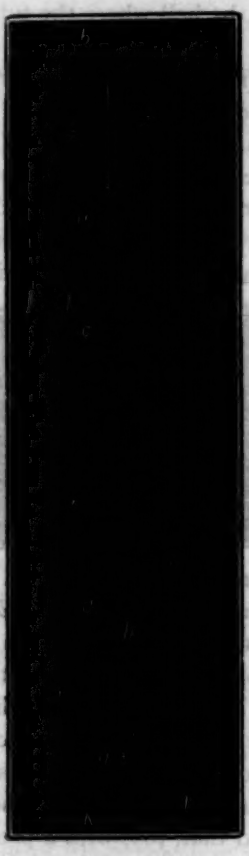
	Pitot Tube.		*Magius Tube.*	
Distance from d.	*Oscillating.*	*Fixed.*	*Oscillating.*	*Fixed.*
0·15	50	50	54	47
0·40	50	51	57	51
0·70	35	35	45	37
1·00	24	24	24	24
0·40	90		93	
0·40	85		95	
0·40	80		90	

Although the oscillation of the tube was scarcely visible, and although the tube was not a long one, yet the error is so considerable in the Magius tube, that the suction could evidently not be used for giving an accurate determination of the wind velocity.

However, I do not regard it as impossible, whenever the opportunity presents itself, to determine at least approximately the amount of error, by calculating the duration of the oscillations

from the length of the tube exposed to the weather; the experiment would not be long in making known the amount of the effect produced by different velocities.

The Magius tube presents, on the whole, by reason of its very simple form, so many advantages that, at least in places where up to the present time the observer has been obliged to be satisfied



with estimating the force of the wind, he will be able to derive benefit by using this tube as an anemometer. If a precise anemometer is desired then we must use the Pitot tube, and I will venture to recommend the following construction, *Fig. 1*.

The iron tube *a* carries at the top the Pitot tube *b* as well as the wind-vane *c* and its counterpoise *d*. At e_1 and e_2 the tube is

fastened by collars fixed to the beams f_1, f_2. The bottom of the tube ends in a steel point which moves in the socket g; a bell h is fixed on the tube and is partly submerged in oil which surrounds the lower end of the tube, and is contained in a reservoir i. Within the bell, but above the oil, the tube is perforated with a series of holes through which the pressure of the wind received in the Pitot tube is transmitted to the bell where the tube K conducts it to the manometer.

In order to draw off the water which comes through the tube a in storms, the tube and cock, l, is used.

The cost of such an apparatus is small. The instrument can be set up so that there shall be no danger of its being overturned by high winds, and for precision, it leaves nothing to be desired.

For a manometer I should recommend using an arrangement a little different from that used in these experiments, to wit, the kind

of letter-balance shown in *Fig. 2*. The bell rests in use as before but in place of a spring, the steel-guard a–b is used, of which the short arm a carries an arc of a pulley on which rests the silk thread c, whilst the long arm moves over the divisions of a scale graduated on another arc d. By giving this arc three or more different graduations which, according to circumstances, correspond to different positions of the weight e, the same apparatus can be used to measure pressure or suction expressed as height of water from 0 to 120 mm., and that, too, with a precision proportional to the smallness of the quantities.

GLASS-MAKING.

By C. HANFORD HENDERSON, Professor of Chemistry and Physics, Philadelphia Manual Training School.

[*A Lecture delivered before the* FRANKLIN INSTITUTE, *Monday, January 10, 1887.*]

PROF. HENDERSON was introduced by Dr. Persifor Frazer, Professor of Chemistry in the INSTITUTE, and spoke as follows:

LADIES AND GENTLEMEN:—It is related that when the Queen of Sheba went to visit Solomon, that astute monarch so arranged his audience throne that the Queen and her suite in approaching would be obliged to pass over a floor of glass, under which was flowing water and fishes swimming. For the legend has it that the wisest of men was decidedly curious. Having heard that his queenly guest labored under the disadvantage of a deformed foot, his ingenuity suggested the device of the flowing water, thinking that the lady's anxiety for her draperies would discover to the King of the Israelites and his court whether rumor had rightly reported her. But I am much disposed to ascribe this performance to the imagination of one later than Solomon. Not only would so inhospitable an act have been notably at variance with the royal genius, but at that time it would scarcely have been possible. Not even the 120 talents of gold and the very great store of spices and precious stones which the admirer of wisdom brought with her as a present to Jerusalem could have purchased a plate of glass sufficiently large and sufficiently clear to have made such a deception possible. In the production of curious works of art in glass, and the fabrication of rare bits of colored ware, the ancients showed themselves scarcely inferior to modern glass-makers, but the magnificent sheet of glass through which we of a morning study the signs of the weather, or admire the tempting display in the shop windows, is a luxury peculiar to our own times. If our age had not already been devoted successively to the genius of iron, of steel, and latterly of electricity, I think we might designate it, not without reason, the "age of glass," so manifold have been the applications of this material.

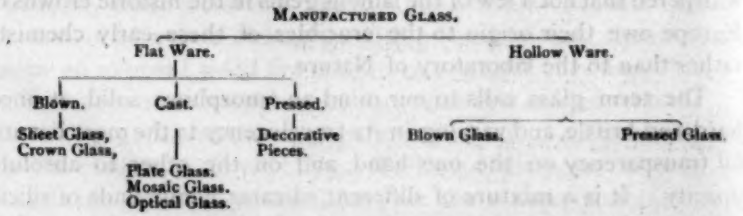
That we must, however, ascribe to glass a great antiquity is beyond question. Some ingenious investigators have carried its origin back to the time of Tubal Cain, the patron of the metallurgist's art, but their following has been very small. The most commonly received story is that told by Pliny and Tacitus, which ascribes the origin of glass to an accidental discovery made by a company of Phœnician merchants. These, it seems, had landed on the sandy coast of Palestine, and in heating their cooking vessels over the fire, made use of soda cakes taken from their cargo, no stones being available for the purpose. The sand and alkali being brought together in the fire, united to form a transparent fluid, and thus, say these historians, the first glass became known. But the formation of even a soda glass with no greater heat than that given by an exposed wood fire is open to chemical question. We have, however, much stronger testimony than this careless hearsay, which shows the fabrication of glass to have been an accomplished fact in the earliest historical times. To Egypt, the home of most of the arts and sciences, we must look for the earliest examples of the blower's skill. On several of the ancient tombs, scenes are depicted which represent unquestionably different stages in the manufacture of glass. But what is even more conclusive, interesting examples of this early art have also been discovered. A glass bead, found at Thebes, and described by Sir Gardner Wilkinson, in his *Manners and Customs of the Ancient Egyptians*, formed at one time a part of a royal necklace. It has engraved upon it the name of Queen Hatason, the wife of Thotmes III, who reigned 1500 B. C. The industry, thus early established, seems to have attained a national importance, for when the country was subdued by Cæsar Augustus, he decreed that a part of the annual tax should be paid in glass. The Romans were not slow in introducing so advantageous an art into Italy, and many interesting examples of their workmanship are now to be found in the museums of Europe. Venice, in particular, became celebrated for the delicate ingenuity of its glass-workers. The ateliers of Murano preserved for many years the best secrets of the blower's art. The gradual spread of the industry throughout the world at large, and especially its development in the countries of Europe, form a story of much interest, and one that I regret time will not permit me to repeat. But even confining our inquiry in time to the present, and

in locality to America, there will be much that must of necessity be omitted. It is to be remarked, however, of these early manufacturers, that for many years glass seems to have been regarded as a material better suited to the requirements of the fine arts than to the demands of every-day life. Hence, it was to be found in the possession of few, save the very wealthy. With this usage in view, the early glass-makers gave more attention to brilliancy of lustre and depth of coloring than to the more useful qualities of transparency and size. In this, it cannot be denied that they met with marked success. Some of the color effects in glass of the Twelfth Century cannot be imitated at the present day, and it is even whispered that not a few of the famous gems in the historic crowns of Europe owe their origin to the crucibles of these early chemists rather than to the laboratory of Nature.

The term glass calls to our mind an amorphous solid, at once hard and brittle, and varying in its translucency to the most beautiful transparency on the one hand, and on the other to absolute opacity. It is a mixture of different silicates, compounds of silicic acid, with the bases soda, potash, lime, magnesia, alumina, iron and lead. Every true glass contains at least two bases united with the silica and generally, by virtue of the impurities associated with the crude materials, traces of several more. We have, therefore, grown into the habit of designating the different kinds of glass by the names of the two principal bases. Thus, we speak of window glass as a lime-soda glass; of flint glass, used for optical instruments, as a lead-potassium glass; of the well-known Bohemian product, as a potash-lime glass, and so on through the list. It is a valuable property of these mixed silicates that they have a fusibility much below the mean of the constituent salts. Thus, while the silicates of alumina, lime and magnesia are almost infusible alone, they become quite manageable when associated with the silicates of soda and potash.

The operation of glass-making is one which involves not only considerable skill in the chemic art, but also not a little familiarity with the principles of physics. I scarcely know which to admire the more, the nicety with which the glass-maker regulates the proportions of his charge, so as to produce this beautifully clean substance, or the dexterity with which he handles the finished product, and adapts it to our uses. The several steps in the pro-

cess of glass-making depend from the very beginning—the choice of the raw materials—upon the purposes to which the glass is to be put. While there is great similarity in the operations of melting, blowing, moulding and annealing, the differences in the several manipulations are sufficiently marked to make it desirable that each special branch of glass manufacture shall be described separately. The processes of fabrication can better be classified by referring them to the character of the product, than to the constitution of the glass. Following this principle, we will find that all the more common varieties of manufactured glass will be included in the following table:



I shall consider flat ware first, as being far the more important of the two main classes. I think you will agree with me that, however convenient and helpful glass may be when applied to the construction of domestic or scientific utensils, its use for these purposes sinks into utter insignificance when compared to its much larger value in filling the windows of our houses, in lengthening our days to the dimensions assigned by Nature, and in permitting us to enjoy the sunshine of out-door life at all seasons of the year without being exposed to the inclemencies of the weather; or its more subtle use in optical instruments, in giving sight to the almost blind, in endowing the infinitesimal world, through the aid of the microscope, with sensible proportions; or by means of the telescope, bringing the infinite regions of space within the scope of human observation. When these uses of the material come up before the mind, glass becomes not only an object of interest from the skill required in its fabrication, but also an object of reverent wonder from the larger universe it has made possible to us.

Among the many industries that have been benefited by the utilization of natural gas, there is probably none in which the results have been so marked as in the manufacture of window glass. For a number of years past, American sheet glass has been

undoubtedly inferior to the product of European factories, and has consequently occupied but a secondary position in the estimation of our builders and architects. The foreign makers, and more particularly those of France and Belgium, have hitherto shown a superior skill in the management of their materials. They seem to have held the secret of obviating the bad effects of impurities in their fuel. This result has been made possible from their greater experience in the industry, and from a better construction of furnaces. In the more perfect plants, crude fuel has been abandoned, and manufactured gas used in its place, thus anticipating the advantages of natural gas, with the important exception, however, of its cheapness and almost total freedom from sulphur. The more favorable conditions prevalent abroad made imported glass synonymous with best quality. That the circumstances of the industry have now so far changed, that American glass-makers can successfully compete with foreign producers of the best reputation, and can even claim certain points of superiority for the home product, is a subject for hearty congratulation. The well-known ingenuity of American inventors has, in a measure, effected this improvement, but perhaps the substitution of gaseous fuel has been the most potent cause of our recent successes. The metamorphosis of the crude material into a clear and brilliant pane of glass involves about the same operations in all our modern factories, but in each establishment the details of manufacture are slightly varied. I shall therefore call your attention to-night to the fabrication of sheet glass as carried out at Pittsburgh, for in that city one can see the best American practice.

The manufacture of window glass depends for its success upon the closest attention to details, and its history is therefore one of delicate manipulations. It is a very easy matter simply to make glass. Sand, alkaline bases and heat are the only elements needed to accomplish the transformation. The iron-master frees his ores from their associated gangue by making it into a fusible silicate of lime and alumina, an opaque glass. The assayer separates his metal from its impurities by adding suitable fluxes until all earthy matters are gathered into a fusible slag, and float above the metallic button as a molten glass. And even Nature, when her local caldrons bubble over in the volcanos, shows that she too is a giant glass-maker. But to make good glass; glass that shall be

clear, transparent, colorless; that shall simulate the purest water of the mountain stream—this requires skill and patience, and not in one part of the process alone, but in all, from the mixing of the crude materials to the annealing of the finished product, the glass-maker must be alert and intelligent.

Window glass, as we have seen, is a lime-soda glass, or a mixture of the silicates of lime and soda. It approaches quite nearly to the composition represented by the chemical formula $CaO, Na_2O, 6SiO_2$. To supply the ingredients required by this formula, the raw material, or "batch" employed, consists of about thirty parts of lime, forty of alkali, and a small but varying amount of pulverized charcoal to each 100 parts of sand, the commercial representative of silica. These are thoroughly ground and mixed together before being introduced into the furnace. Some manufacturers make their alkali all sulphate of soda, while others employ a mixture of sulphate and carbonate in the proportions shown by their experience to give the best results. Not only does the composition of the alkali vary greatly, but the relative amounts of the three components of the batch are different in every establishment, and even in the same establishment vary in accordance with the quality of the crude materials.

Where gas is used, the construction of the melting furnace is very simple. A plain rectangular floor or hearth gives support to eight or ten glass pots, standing two abreast; a series of round openings on each side of the furnace permits free access to each pot; the gas is admitted at each end and is mixed with air which has previously been heated by passing through chambers in the fire-brick arch. An intense heat is thus obtainable, and one that has the advantage of being under the most complete control. A well is built under the furnace in order to collect the molten glass should a pot break, and so avoid loss of material or stoppage of the work. An arch is provided at each end of the furnace to permit the admission or removal of the pots. When the furnace is in blast the opening is closed by fire-bricks and luted with clay.

The manufacture of crucible pots is the most tedious and exacting process connected with glass-making. It requires constant care, for if the treatment be in any way imperfect, the entire subsequent work of the crucible will be unsatisfactory. At Pittsburgh, the pots are generally made up of a mixture of two parts raw fire-clay, two parts burned fire-clay, and one part ground pot shells. The

well-ground mixture is placed in lead-lined bins or troughs, and sufficient water added to make the mass plastic. It is turned once a day for a period of about four weeks. The workman kneads the mass with his bare feet in order to make it tough and free from air. In this country the pots are generally formed by hand, the temperature and humidity of the work-room being kept as nearly constant as possible. The bottom of the pot is first formed, and then the sides built up gradually from day to day, the entire process occupying about six weeks. The uncompleted walls are always left covered with damp cloths in order to prevent premature hardening. The pots are ordinarily made 33½ inches deep, and 42½ inches across the top. The thickness varies from 3½ inches at the base to 3 inches on top, while the bottom is 4 inches. Their capacity is from fourteen to sixteen hundred pounds of molten glass. When the pots have been completed, they are are permitted to stand in the work-room for several months in order to dry very gradually. They are then placed in small heating furnaces, where the temperature is slowly raised to that of the melting furnace. The transfer from one to the other is made as quickly as possible. The interior of the crucible is then glazed with molten glass, and is ready to receive the raw materials.

One-third of the charge is first placed in the pots, and allowed to melt before the addition of the rest of the batch. If the furnace is in good condition, the melting proceeds from below upwards, the cone of raw material gradually sinking into the bath of molten glass. If this does not occur, if the fusion begins on top, it is a very plain indication that the heat has not been properly regulated, and that a long period will be required to accomplish the complete melting of the charge. At the end of about four hours another third is added, and after a similar interval of time, the remainder of the batch is finally introduced. About two pounds of arsenious acid are put in with the last charge, in order to bleach the glass by converting the iron present into a higher oxide. At some establishments, the peroxide of manganese is used to accomplish the same purpose, but it has the disadvantages of giving the glass a pinkish color if used even in slight excess. It is also believed to make the transparency of the glass less durable.

Some years ago, an excess of manganese was employed intentionally, in the manufacture of window glass as it was thought that

a pretty face looked prettier when seen through rose-colored glass. Some of you doubtless remember having seen this decidedly pink glass in not a few of the older houses of the city. It may indeed be seen at the present time even, for its use was revived by the severe hail storm of seventeen or eighteen years ago, when the neglected manganese glass was again brought into requisition by the emergency.

After the contents of the pot have become quite liquid, a capping of broken glass is added to fill them up completely. The entire melting of such a charge occupies about sixteen hours. During the latter portion of this period, the heat is somewhat reduced to make the glass less liquid, and prepare it for gathering. But first, the surface of the molten "metal" must be freed from all impurities by skimming. A fire-clay ring, which was introduced into the pot when it was first put in the furnace, floats upon the bath, and the gatherer, by removing all the scum from the interior of this ring, always has a clear surface from which to draw. The glass is gathered on the end of a wrought-iron blow-pipe, about five feet long, the end of which is decidedly flared. The first dip brings out but a small lump of glass, which is gotten into symmetrical oval shape by a careful turning of the pipe. Three times the process is repeated, until the gatherer has a mass of from fifteen to twenty pounds of glass on the end of his pipe. When window glass of double thickness is to be made, the metal must be gathered as many as four or five times. The resultant ball in this case weighs from thirty to forty pounds. It is at the final dip that the gatherer's greatest skill is called into requisition. To get the mass of red-hot plastic glass into symmetrical shape, and satisfy himself that it is thoroughly homogeneous throughout, he rests his pipe on a convenient fulcrum, and by a rapid revolution while the end carrying the glass is still in the furnace, causes the last glass added to completely overlap the former ball. The entire mass is brought almost to the liquid condition, and by a skilful manipulation of the blow-pipe, the fold of glass is turned into a spiral and worked to the end of the mass. The red-hot ball of glass is now taken to a wooden mould, and by a few dexterous turns is formed into a pear-shaped ball. The mould is kept from burning by being constantly moistened with water, which, in contact with the heated glass, assumes a spheroidal condition, and looks like so many

globules of mercury. When this has been accomplished, the gatherer's duty is at an end, and he hands pipe and glass over to the blower.

In France and Belgium, the same furnace is generally used for both melting and blowing, but in England and this country it is found not only more convenient, but even more economical to use separate furnaces. The blowing furnace adapted for gaseous fuel is similar in many respects to that used for melting. It is constructed with a series of side openings, somewhat larger in diameter than those of the former, and simply provides an intensely hot chamber for controlling the temperature of the glass while being blown. The gas, however, instead of being introduced at each end, is burned directly under the openings, or blow-holes. The requisite amount of air is mixed with the gas by means of fire-clay chimneys surrounding the burners in a manner precisely similar to the chimney in the Bunsen burner. In order to prevent the flame from impinging directly upon the glass being manipulated, fire-clay slabs or bricks are placed a short distance above each burner, and thus divide the flame into harmless jets.

In the most completely equipped works, the division of labor is carried into thorough practice. Each man knows how to do one particular thing, and does it. The blower, for instance, into whose hands the red-hot ball of glass has just been consigned, knows nothing of crude materials, melting processes or molten baths. Nor, on the other hand is he supposed to have more than a vague conception of what is meant by a pane of glass. His crude material is the pear-shaped mass on the end of the blow-pipe; his finished product, a large cylinder of glass. The skill with which he affects his part of the many transformations required in the genesis of a window pane is, however, the most attractive in a process nowhere devoid of interest. His first act is to grasp the pipe, and with the ball of glass still resting in the mould, blow through the mouth-piece until a large bubble of air is formed in the mass. Then, with alternate blowing and manipulating, he increases the bubble, until the mass assumes a shape not unlike that of the large carboys used in the transportation of acids. On each side of the furnace, and directly in front of the openings or blow holes, there is a wide platform, the long openings in which, running at right angles to the furnace, permit the blower to swing

his pipe and ball of glass in a pit beneath. Blowing, swinging and heating, he extends the bubble, until in place of the ungainly carboy, with its disproportionately thick bottom, he has a beautifully symmetrical figure, the shape of an enormous test tube. From time to time, however, during these operations, it happens that the glass flows a little too freely, and that there is danger of the sides of the cylinder becoming too thin. To avoid this result, the blower throws his cylinder into the air whenever he finds that the glass is too liquid, and so permits it to settle back upon itself. The tube being by this time about five feet long, and the blow-pipe as many more, one can readily fancy that this apparently playful toss requires both skill and muscle. In the case of the larger cylinders, such as will furnish a pane 66 x 54 inches, and which must be made of double thickness, the labor is so great that few men are found who are capable of its performance.

When the tube has been formed to the satisfaction of the blower, he allows it to become comparatively cool. He then thrusts the end into the furnace, blows into his pipe, and quickly covers the mouth-piece with his hand. A slight report is soon heard. The end has become softened with the heat, and the confined air, expanding with the increasing temperature, has blown a hole in the glass. Resting his pipe on a suitable support, and still keeping the glass in the furnace, the blower gradually turns it around. Under the influence of this centrifugal force, the hole grows larger and larger, until he no longer has a test tube at all, but in its place an open cylinder. This is quickly withdrawn from the furnace, and permitted to depend into the pit below, until the plastic edge passes to a cherry heat, and the cylinder can be taken away without danger of getting out of shape.

The blower's part is now completed, and after a moment's rest, he has another pipe in his hand, and is repeating his heavy labor.

The neck of the cylinder and its attached blow-pipe are separated from the cylinder proper by wrapping around the end of it a thread of red-hot glass, and after its removal, applying a piece of cold iron to any point heated by contact with the thread of glass. A red-hot iron is also passed along the interior surface from end to end, making a longitudinal crack; or the same result may be effected by means of a diamond attached to a long handle. We have now a perfect cylinder, open at both ends, and having a crack

its entire length. Another step in its transformation into a window pane has been accomplished.

The cylinder is now taken to a separate building to what is known as the laying-in furnace. The hearth is made circular, and is divided into a number of sectors, separated from each other by fire-clay bridges. As the hearth revolves, the different sectors move through as many separate compartments of the furnace, the temperature of which may be varied at pleasure. The first compartment, which is only moderately warm, is known as the laying-in oven, and permits the cylinder to become gradually heated. A partial revolution of the hearth then carries it to the next compartment, the laying-out oven, where the temperature is sufficiently elevated to make the glass plastic. A large flat stone, manufactured out of fire-clay, prepared with the greatest care, occupies the floor of each hearth sector, and is adapted to receive the cylinder. In the laying-out oven, the crack is brought uppermost, and under the influence of the heat, the cylinder gradually unfolds until it lies open on the stone like a sheet of rumpled paper. In the next compartment, the flattening oven, a workman irons out the plastic sheet with a moistened block of wood on the end of a long rod until it is perfectly smooth and flat. The smoothed sheet, by another revolution of the hearth, is taken to the compartment known as the dumb oven, where it slowly cools. A final revolution of the hearth brings it to the entrance of the annealing leer, next door to the laying-in oven, thus making the circuit complete. The process, you see, is quite continuous, and by a few simple operations transforms the cylinder into a flat sheet of glass. But still it is not ready for use. Were the glass taken from the dumb oven and permitted to cool in the air, it would be so brittle that it would be almost without value. It must therefore go through the process of annealing, or gradual cooling, before it can become serviceable.

The most improved annealing oven is that known as the "rod leer," which has come into general use in Pittsburgh, and other localities where the best practice is followed. When the glass reaches this stage of its journey, it is picked up with a large two-pronged fork, and is placed upon a series of rods projecting from the mouth of the leer. These are found an immense improvement over the cars formerly used for the purpose. They handle each

sheet separately, and are so arranged that when it is desired to make room for a fresh sheet, a part of the rods may be raised and carry the contents of the entire leer towards the cooler end, where all the sheets are eventually discharged. The glass remains in the leer from thirty to forty minutes, in place of several hours or days, as in the old-fashioned annealing ovens. When the glass is discharged, it is nearly or quite cold, and may be at once cut into proper sizes and stored in suitable frames.

This, with the exception of the important commercial transaction of converting the glass into money, completes the process in window-glass manufacture. In all departments of the work, the advantages derived from the use of gaseous fuel are becoming each day more evident. If you will examine, even casually, the differences between gas-made glass and the older article made with coal, you cannot help being struck with the manifest superiority of the new product. The surface of the glass, just as it comes from the furnace, is remarkably brilliant, and quite as beautifully clear as if it had been washed with hot water by some careful housekeeper, and dried with linen. A better and more thorough fusion is obtained from the more intense heat of the gaseous fuel, and, what is even more important, the contamination of the "metal" by particles of coal and cinder is entirely avoided. In the latter part of the process, in flattening out the glass cylinders, the advantages of gas are particularly manifest. When coal was used, the sheets of glass came from the laying-out oven covered with smoke, and infinitely worse than that, a white deposit of sulphur. It must be remembered that these impurities were gathered while the glass was in a semi-plastic condition, and that in consequence, no subsequent washing or acid bath could entirely restore its brilliancy. The contrast between the two fuels, gaseous and solid, is perhaps still better shown by a glance at the history of those establishments which are not so fortunate as to possess it. Quite a number of large glass works throughout the West have admitted that the competition with the factories supplied with natural gas is too unequal, and have either suspended operations or have transferred themselves to the shadow of the nearest gas derrick. Several such migrations have been reported during the past year, and where this has not been possible, manufactured gas has in a number of cases taken the place of the crude fuel.

The manufacture of crown glass, though commercially much less important than that of sheet glass, possesses considerable historical interest, and within the past year or two has been brought into some prominence again from the use of the material in decorative windows. It possesses a brilliancy far superior to that of its younger rival, but the small size and unequal thickness of the panes obtainable, do not permit it to successfully compete with the generous dimensions and constant uniformity of the sheet glass. The glass itself is alike in both, the differences between the two being due entirely to the subsequent manipulations, after the melting process has been completed. As before, the glass by several successive gatherings is collected on the end of the blow-pipe, and by rolling on a table of metal or stone, known as the marver, is gotten into the shape of a cone, the apex of which forms the so-called "bullion point." The workman now blows into his pipe, expanding the glass into a small globe. This is subsequently enlarged, care being taken to keep the bullion point in the line of the blow-pipe. The globe is then flattened to something of the shape of an enormous decanter, the bottom being very flat, and having the bullion point in its centre. The pipe and its burden are now permitted to rest horizontally upon two iron supports. In the meantime, another workman has gathered a small lump of glass upon the end of his iron rod or "pouty," and by pressing it against an iron point, has impressed upon it the shape of a small cup. This is fitted over the bullion point of the glass, and soon becomes firmly attached to it. The blow-pipe is separated from the glass by means of cold iron and a sharp blow. The open neck thus exposed is known in the glass-worker's parlance as the "nose," and gives its name to the furnace where it is subsequently re-heated. During this operation, the pouty is constantly and rapidly revolved. Under the combined action of heat and centrifugal force the nose gradually expands, the opening growing larger and larger until the piece has the shape of a typical crown. But this appearance remains only an instant, and in its place is seen a brilliant circular plate of glass, whose shape is only maintained by continuing the rotation of the pouty until the plate, or table as it is now called, can be laid upon a flat support. The pouty is then detached from the bull's-eye by means of shears. As soon as they are sufficiently cool to be rigid, the tables are stacked in annealing

ovens where they remain from one to two days. Their diameters vary from a few inches to six feet, but the latter dimension is extreme. After annealing, they are divided by a diamond into two unequal parts, the larger of which contains the bull's-eye. It can readily be imagined that a semi-circle of glass, which has even the extreme radius of three feet, cannot be cut into square panes very advantageously, and this consideration, together with the small sizes necessary in crown glass, have more than counter-balanced its admirable brilliancy.

At the present time, crown glass, in the circular form, just as it comes from the annealing oven, is being used in decorative windows with very excellent effect. The glass is frequently tinted, amber being a special favorite, or else it is white, with the bull's-eye colored. A very effective window of this sort may be seen in the hallway of the Tiffany Glass Works, in New York. It consists simply of a succession of crown glass tables, perhaps eight to ten inches in diameter, having opalescent and tinted bull's-eyes. The use of the bull's-eye alone is also becoming quite popular in mosaic window glass.

Sheet and crown glass are the chief representatives of the blown ware in the flat. I have described their manufacture in some detail, from the feeling that the former, at least, is the most important of all the products of the glass-maker's art. In the next division of our subject, we shall be brought to a consideration of a class of products, those obtained from casting, which are far more beautiful and wonderful than the former, which, since they affect the welfare of a smaller proportion of the civilized world, must be ranked economically of less importance.

Following the order given in our table, we shall next take up the manufacture of plate glass, and for this purpose I shall again ask your presence in Pittsburgh. This time, however, our visit will be to Creighton, some twenty miles north of the city, and near to the well-known natural gas district of Tarentum. There are in this country four large establishments where plate glass is manufactured. The Creighton plant has the reputation, however, of enjoying the most favorable economic conditions, and it would certainly be difficult to find in this or any other country one more completely equipped. The glass itself has the same constitution as the sheet and crown glass. It is simply a double silicate of lime

and soda. The melting is carried out in large open pots, the furnaces differing in their construction from those already described, only in their greater size and the substitution of doors made of fire-clay tiles set in cast-iron frames for the usual gathering holes. When the fusion has been completed, the door opposite the pot is opened, and a two-pronged fork, mounted on wheels, is inserted into the furnace. The distance between the prongs is sufficient to permit them to pass into depressions made in each side of the melting pot, and thus secure it in a firm grasp. By this method, the pot of molten glass is removed from the furnace, and is carried on a low truck to the casting table. At Creighton, the casting house, containing furnaces, tables, and annealing ovens, is 650 x 160 feet, about four times as large as the famous *halle* of St. Gobain, in France, and nearly double the size of the British Works at Ravenhead. There are two casting tables at Creighton, 7 inches thick, 19 feet long, and 14 feet wide. Each is provided with an iron roller, 30 inches in diameter, and 15 feet long. Strips of iron on each side of the table afford a bearing for the rollers, and determine the thickness of the plate of glass. The tables are mounted on wheels, and run on a track which reaches every furnace and annealing oven. The table having been brought as near as possible to the melting furnace, the pot of molten glass is lifted by means of a crane, and its contents quickly poured on the table. the heavy iron roller is then passed from end to end, spreading the glass into a layer of uniform thickness.

As rapidly as possible, the door of the annealing oven is opened and the plate of glass introduced. The door is then closed, and the glass left to anneal. All of these operations are performed in little more time than it takes to describe them, as it is desirable to get the glass into the annealing oven as hot as can be. A large number of ovens are required for annealing purposes, as the glass must remain several days to cool. When the glass is taken out, its surface is found to be decidedly rough and uneven. A small quantity is used in this condition for sky-lights and other purposes where strength is required without transparency. It is known in the market as rough plate. The greater part of the glass is ground, smoothed and polished before it leaves the works. The grinding is accomplished by means of rotary grinding machines, the abrading material being common river sand dredged from the

Alleghany. Three million bushels are required annually for this purpose. The plates are firmly fixed on large rotary tables or platforms by means of plaster of Paris. Rotating discs are so arranged that they cover the entire surface of the glass at each rotation of the platform. Small jets of water keep the grinding sand always wet. These operations remove the rough exterior. The smoothing is accomplished by emery, finer and finer grades being used as the process proceeds. The final polishing is done by means of rouge (carefully calcined sulphate of iron). The monthly product of the Creighton plant is about 100,000 square feet of glass. The fuel throughout the entire works is natural gas, which here displaces about 3,000 bushels of coal daily. It is used in melting furnaces and annealing ovens, as well as in supplying the steam for engines of about 1,500 aggregate horse-power. These figures will give you some idea of the magnitude of the operations connected with a large factory and will perhaps dispel the notion, if such exist, that we are largely dependent upon France for our supply of plate glass. The output of this factory, though so large, finds ready market and is never greater, I understand, than the demand; for the American plate glass can compete both in quality and price with that of European make. At Creighton, a part of the output is utilized in the manufacture of mirrors, and improved bevelling machinery has been introduced in order to give the glass the desired finish.

The subject of colored glass windows is a very large one, and whether viewed either from the artist's or technologist's standpoint would be difficult to exhaust. In its nomenclature, we have permitted ourselves to fall into rather careless habits. The terms "painted," "stained" and "mosaic" glass are used indiscriminately to designate any glass work involving color, but a moment's consideration will show them to be far from synonymous. Some of our best effects are produced without the use of either paint or stain, and they have the advantage of a much greater durability. In painted glass the colors are obtained by enamels fused to the surface of the glass by means of heat. In stained glass, a permanent, transparent color effect is secured by the action of heat on certain metallic oxides applied to the surface as pigments. In mosaic glass, pure and simple, the design is brought out by the use of shaped fragments of colored glass bound together by strips of

doubly-grooved lead. The three products, you see, are quite distinct. It frequently happens, and in the older examples of ecclesiastical design it is nearly always the case that all are combined in one window. But at the present time there is a strong reaction against the employment of either stain or paint, since they are less durable and less brilliant than homogeneous colored glass. The tendency is very decided to rely entirely upon the mosaic treatment, and to limit the use of paint to the representation of the human body. Even here it is reduced to a minimum by employing a translucent glass and shading sparingly in monochrome. A light reddish-brown is the favorite tint. It has the disadvantage of giving a statue-like sameness to all the figures. Should the present taste continue, our picture windows promise to become an assemblage of rather monotonous blonde types.

The manufacture of mosaic glass at the present time has attracted the attention of men of such ingenuity and taste that it deserves its rank among the fine arts. It has attained a degree of artistic perfection, of which the earlier examples gave little promise. In spite of the abandonment of paint and stain, the mosaic glass has been given greater variety and greater depth of color than at any time since the Renaissance. The glass itself has been made in all the colors of the spectrum, and has undergone a thousand different transformations. By the mixing of several colors when the glass is no longer liquid, curious mottled effects have been produced, while the addition of cryolite and other indissoluble substances has given us the opalescence so much admired in the art glass work of the last few years. The shapes have been no less varied than the colors. The so-called "jewels," or pieces of richly-colored glass, cut with facets after the manner of precious stones, have added immensely to the brilliancy of modern designs. I had recently the pleasure of going through a factory for colored glass in Brooklyn, probably the largest establishment of the kind in this country, and I assure you that it was a chromatic treat to visit their storerooms, for 500 different color combinations were recognized in their stock. The mosaic ateliers of the Vatican contain, it is true, some 26,000 different tints; but these, you must remember, are simply opaque enamels, while the glass of which I speak is all easily translucent, and much of it is clearly transparent. Time will not permit me to give you anything like an exhaustive

description of this branch of glass manufacture, but the subject is far too interesting to be passed over in silence. The basis of the process is, as before, a lime-soda silicate, the coloring being due to the addition of soluble metallic oxides. Taking them up in the order of the spectrum, the violet shades are generally produced from manganese or from small quantities of cobalt; the deep blues, indigos, purple blues, and normal blues are obtained from varying proportions of cobalt; peacock blue from copper, the finest greens from chromium and copper, and the dull sea-water tint from ferrous oxide. The yellows come from a variety of sources. The sesquioxide of uranium gives a fluorescent yellow; the oxide of lead, a pale yellow; the oxide of chromium, an emerald-green; and the oxide of silver, applied as a pigment to the surface of the glass, a permanent yellow stain. The higher oxide of iron gives an orange color, but as it has a strong tendency to become reduced, it is necessary during the manipulation of the glass to keep some oxidizing agent present, such as manganic oxide. In the reds, a number of excellent shades are readily obtainable. Manganese furnishes a variety of pinkish-reds and pinks; copper in its lower oxide, the fine blood-red of Bohemian glass, and gold, the most brilliant of all reds, the well-known ruby color. In addition to these, a number of other substances are used to produce either colors or unique effects. A little carbonaceous matter yields an amber tint of very agreeable hue, while the opalescence now so much in vogue results from the presence of oxides of tin, arsenic or lime, or from native minerals, such as fluorite, or the cryolite imported in such large quantities at the present time from Greenland. If simply colored, transparent sheet glass is to be made, the molten metal may be gathered and blown into cylinders in precisely the same way as in the manufacture of window glass, but in mosaic glass it is now much preferred that the glass employed should not be transparent, or but imperfectly so, since the color effects are much richer from uneven surfaces. The most of the glass is therefore cast, the process being a repetition in miniature of the casting of rough plate. The pots containing the molten colored glass remain, however, always in the furnace, and the metal is dipped out in small iron ladles. It is poured at once on a little casting table, and is smoothed out by means of an iron roller. The sheets being so small, are readily handled and permit the use

of the convenient rod leer. In case more than one color is to appear in the same sheet, the effect is obtained by mixing the several masses of plastic glass on the casting table by means of a copper implement not unlike a plasterer's trowel. In this way three or even four colors are mixed together in the same piece of glass, and though the results are always more or less experimental, artists have learned to adapt them not only to their geometrical designs, but also to their picture windows as well. The workmen have attained no little skill in the art of mixing. The blue and white translucent glass in particular is made to represent sky effects almost as naturally as if the colors had been laid on by an artist's brush. From the factory the glass is taken to the studio. A number of preliminary steps must be taken before the actual work of putting the glass together can begin. The artist first makes a sketch of his design, and then, if satisfactory, enlarges it to the natural size. This working drawing is then colored and divided up by broad black lines representing the strips of lead necessary to hold the pieces of colored glass together. The cutting of the glass is a severe tax upon the judgment, and has to be carried out under the immediate supervision of the artist. In geometrical designs, the requirements of color harmony alone need attention; but in picture windows, in addition to this, a very appreciative eye is needed to seize upon just the right combinations to bring out the draperies, background and sky, for no paint or stain is used in the entire picture except the monochromatic shading representing the head and other exposed portions of the figure. There are in this country a number of establishments where work of such a character is done. The Tiffany Glass Company of New York have been particularly successful in adapting the mosaic treatment to picture windows. They have recently reproduced Gustave Doré's famous painting, "Christ Leaving the Prætorium," for a church memorial window, the entire piece being executed in pure mosaic, with the exception of the faces and hands. The dimensions of this truly magnificent work of art are 20 x 30 feet. It is the most ambitious window ever attempted in America, and indeed the largest opalescent piece in the world.

The glass employed in optical instruments must needs be as dense as possible, since its refractive power increases with its specific gravity. We employ for this purpose, therefore, a mixture

of the silicates of lead and potash. But as these compounds differ greatly in their respective densities, much care must be taken to prevent their separation, and the consequent streaky structure which would result. The sand, red oxide of lead and potash, having been mixed in the proper proportions; that is, so as to produce a glass having approximately a composition represented by the formula Pb O, K_2 O, 6 Si O_2, are introduced in small quantities at a time into a melting pot provided with a dome-shaped cover. This excludes smoke and other impurities, and at the same time prevents the furnace gases from reducing the lead to the metallic state. During the fusion, the mass is frequently stirred by means of a fire-clay cylinder, attached at right angles to a long iron handle. When the fusion is judged to be complete, the furnace is reduced to a lower temperature, and the melting pots permitted to remain at rest for perhaps a couple of hours, in order that all the bubbles throughout the mass of glass may come to the surface. A constant stirring is then maintained for another two hours. In the meanwhile, the temperature falls so low that the stirring towards the end of the period becomes quite difficult. When the operation ends, the clay cylinder is withdrawn, all the openings to the furnace are closed up, and crucible and contents are allowed to gradually cool. This requires about a week. The crucible is then taken out and carefully broken, so that it may be separated from the mass of flint glass. Parallel faces on the sides of the mass are ground and polished in order that the internal defects may be located, and the glass cut up to the best advantage. Those who have been interested in watching the equipment of the Lick observatory, on Mount Hamilton, in California, will perhaps remember the repeated trials that were necessary before the glass for the great telescope could be successfully cast and placed in the hands of Alvan Clarke for grinding. The subsequent processes of adapting the material obtained at the cost of so much labor and expense to optical uses, though of much interest, scarcely come within the limits of to-night's inquiry.

Of the flat ware, then, a word only remains to be spoken concerning the pressed decorative pieces now used with such excellent effect in domestic architecture, and in the ventilators of the newer designs of cars. The process of manufacture is very simple. The molten colored glass is taken from the crucible in a small ladle,

and by virtue of the rapid cooling induced by contact with the cold iron, is in a condition of plasticity by the time it reaches the press. Here it is quickly pressed between the two pieces of the mould, the excess of glass being squeezed out between them in so thin a sheet that it can readily be detached from the finished product. Quite a variety of shapes and designs are now manufactured. Rectangular pieces, stamped with simple flower or geometrical designs, are becoming quite popular for small windows and transoms. Circles, squares, and other pieces are also being made in quantities for introduction into mosaic glass work, and form an agreeable feature in the design.

In the manufacture of hollow ware in glass, we have two distinct processes producing characteristic products, the blown and the pressed glass. The first of these includes all vessels which owe their form to the blower's breath. In considering the manufacture of window glass we have seen the facility with which a mass of glass when in a plastic state may be made to expand into a hollow globe or cylinder at the will of the operator. This same agency, the blower's breath, when a little more daintily applied, furnishes our tables and laboratories with the manifold forms of glass ware which add so much to our daily convenience. In its chemical composition, the glass used for this purpose varies considerably. The celebrated Bohemian glass, which cannot be surpassed in brilliancy by crystal itself, is a silicate of potash and lime with small quantities of iron and alumina. Much of the commoner table ware is similar in its composition to window glass, but possesses little brilliancy and has frequently a greenish cast due to the presence of the lower oxide of iron. The so-called crystal, which in England is sometimes denominated flint glass, owes its weight and refractive power to the presence of silicate of lead. Like the product employed for optical purposes, it is in the main a double silicate of potash and lead, but contains less lead than the latter glass, and has consequently a lower specific gravity. It is the material employed for the fabrication of cut glass and the finer grades of table service.

In the manipulation of the plastic metal, two methods offer themselves to the choice of the glass-worker. In the one, he forms his articles entirely in the air by the dexterous use of a few simple tools, and in the other he depends upon a cast-iron mould to give

the desired shape to the exterior, while the interior is formed by the pressure of his breath. The use of moulds, though common in the manufacture of the cheaper grades of glass ware, and of much importance in bottle-making, is prohibited in the case of the finer goods since, it robs the glass of much of its brilliancy. There is a peculiar polish, which comes from working the glass in the air, not unlike that characteristic of crown glass. It is more than sufficient to compensate for the greater time required by the process. The blow-pipe used in making these smaller articles is a light wrought-iron tube, from four to five feet long and having a diameter hardly greater than one-fourth of an inch. The mass of molten glass gathered on the end of the blow-pipe is compressed and worked into symmetrical shape, by being rolled on a marver. A little air introduced into the interior of the mass transforms it into a bulb, which is then lengthened by swinging. So far, the process is the same whatever may be the ultimate form impressed upon the glass. The subsequent treatment of the bulb is determined by the shape of the article which it is desired to produce. If, for instance, a wineglass or goblet is to be made, the bulb is extended to the proper size to form the bowl, and the stem formed either by drawing out a part of the substance of the bulb itself, or by attaching a small mass of glass to the bottom of the bowl, and while still red hot, drawing it out into the desired shape. The glass worker distinguishes the first as the "straw stem," and the second as the "stuck shank." The partly formed goblet is now ready for its foot. This is either blown or cast, the choice being quite independent of the nature of the stem. The blown foot is formed on a separate blow-pipe, and when attached to the stem, is simply a bulb of glass somewhat smaller than the bowl. The bulb is then opened, and by a rapid twirling of the glass expands into a circular plate forming the foot of the wineglass or goblet. The addition of a cast foot is brought about in a somewhat different manner. A small mass of molten glass is dropped on the end of the stem, and is flattened into the requisite shape by being pressed between slabs of wood or prepared carbon. The original blow-pipe is now separated from the upper half of the bowl, and the rough edge of glass trimmed off by means of shears. In case the article to be manufactured is a pitcher, or other vessel with a handle, the hollow body is first formed, and the handle generally

added in a separate piece. This is attached at one end to the glass, and is drawn out to the desired thinness. The requisite length is then cut off and the free end made fast to another part of the glass vessel. There is in this department an immense variety of shapes and sizes manufactured, each style calling into play some particular adroitness in the management of the molten glass. All of the tools employed are extremely simple, the results depending almost entirely upon the manual dexterity of the workman.

The pressed glass in hollow ware is a variety attaining increasing importance. It is not so brilliant as the blown glass, but at the present time is made in very attractive shapes, and has the merit of low cost. The process of manufacture is similar to the pressed window pieces. The red hot plastic glass is pressed between a fixed mould and a corresponding plunger actuated by hand power. In the flat pieces, such as dishes and plates, the designs used in cut-glass have been reproduced with fair success. They can readily be detected, however, from the genuine article by their inferior brilliancy, and also from the indistinct, rounded appearance, which in glass seems inseparable from angles produced by fusion. In the case of decanters, cruets, and the like, made to imitate cut-glass by being blown in moulds, the deception is now frequently heightened by the use of real cut-glass stoppers. The practice of cutting and grinding the facets in pressed glass has prevailed to some extent, but the surfaces so treated lack the brilliancy of the uncut glass, and so gain little by the operation. The genuine cut-crystals, whose rainbow beauties have made it admired above all other products in glass, is made either from blown ware or from pressed, with perfectly plain surfaces. In this way, the cutting is made to penetrate beneath the chill produced by the mould, and to develop the full chromatic possibilities of the glass.

The manufacture of bottles is a distinct and very important division of the making of hollow ware. It is nowhere in America carried on so extensively and so successfully as in the neighborhood of Philadelphia. Much of the sand of Southern New Jersey is sufficiently pure to make an excellent bottle glass. Its adaptability for this purpose seems to have been appreciated by the early settlers, for the oldest glass works in this country are those established, in 1775, at Glassboro. These works, the property of Messrs. Whitney Brothers, are also at the present day the most

extensive, employing, as they do, some 600 persons in the conduct of their operations. It is a significant fact, showing the force of modern progress, that, after existing for more than a century, the capacity of the plant has been increased more than fifty per cent. during the past three years. As this gratifying result is largely, if not entirely, due to the introduction of improved furnaces, invented by the chemist of the works, Mr. Andrew Farrari. I shall call your attention briefly to their construction. They are, in a word, tank furnaces, heated by gas. Neither the employment of a tank in place of separate crucibles nor the substitution of a gaseous for a solid fuel is in itself new; but the details of the Ferrari furnace are quite novel.

In Europe the regenerative system of Siemens has been employed with marked success in the manufacture of glass, but unfortunately the Siemens furnaces are expensive in their construction, and require some degree of skill to ensure their best working. The Ferrari furnace is an inexpensive affair, and possesses several features of decided advantage. The gas generator is the usual inclined or "step" grate employed by Siemens, but is placed directly alongside of the furnace, thus obviating the transportation of the gas and the necessity of reheating it before being burned. The carbon of the coal is burned on the grate to carbon dioxide, and rising through the mass of incandescent fuel above it, is reduced to the monoxide, and with the volatile hydrocarbons given off passes at once to the melting chamber above the tank. The air necessary for combustion is heated by passing through chambers in the lower portion of the furnace. It is mixed with the combustible gases just before they reach the fire-clay bridge separating the generator from the melting tank. The operation of the furnace is continuous. The crude materials of the batch are introduced at intervals of three hours, about two and one-half tons making up the charge. As the material melts it sinks to the bottom of the tank and flows through small openings leading to the gathering chamber beyond. The glass resulting from the fusion of the sand and alkaline bases has a specific gravity greater than the crude material from which it is formed, and consequently seeks the lowest level. In this way, the tank, though filled with material in all stages of transformation, has always at the bottom a bath of thoroughly fused glass. The communication between tank and

gathering chamber is so arranged that the fluid glass alone can pass from one to the other. There are three Ferrari furnaces in operation at Glassboro the largest of which has a capacity of fifty tons. I am told, on very reliable authority, that not only is the quality of the glass much improved by the employment of these furnaces, but that in addition the experience of three years has shown their maintenance and operation to be notably less expensive than the old style pot furnace. During July and August, the furnaces are out of blast, as the heat is too great to permit the men to work. For ten months, however, the operations are continuous, the necessary repairs being so light, that they do not interfere with the work. In its composition, three grades of bottle glass are recognized. The ordinary green glass is obtained from a change of 100 parts of sand, eighteen parts of sodium carbonate, twenty-two parts of sodium sulphate, and twenty-four parts of lime. As no bleaching agents are employed, the iron present in the sand gives the glass its characteristic light green color. The second grade, the amber glass, has about the same composition, but is colored by the addition of about three-eighths of one per cent. of carbon. The finest of the bottle glass—the so-called flint glass—is obtained from a charge of 100 parts of sand, thirty-five parts of refined soda, and twenty parts of limestone. Manganese dioxide, arsenious acid and nitrate of soda are used as bleaching agents. The bottles are formed entirely in moulds, the blower's breath giving shape to the interior. Where the bottles are very small, one man is able to blow as many as 400 dozen in a day, but this means very dexterous work.

The glass markets of to-day are particularly rich in unique products. The fine cameo ware, made by casing colored glass objects with a layer of another color, and cutting away so much of the second layer as to leave the design in delicate relief; the filigree ware, the aventurine vases, the frosted ware, the crackle ware, the spun and woven glass, and a hundred other beautiful and ingenious varieties of glass work, all have stories of wonderful interest to tell, had we but time to question them. In its employment for utilitarian purposes as well, glass has shown itself quite as adaptable as in the ornamental arts. Every day brings so many propositions for the application of the material to some new purpose, such as for fence posts, railroad sleepers and the like, that I

may safely leave the completion of the list to your imagination. Of the use of glass in the construction of houses, you have all probably received some hint, as well as what the persons who live in such houses should not do.

The PARTICLE in the ROTATING TUBE.

By Irving P. Church, C.E., Cornell University.

It is hardly necessary to lay stress on the importance of inculcating and vindicating correct principles of mechanics in a journal of this character, and I therefore venture a brief response to Mr. Frizell's article, in the recent July number (pp. 67–71), in the hope that, now he has conceded one term of his formula to be erroneous, two simple tests may be conclusive in convincing him that the whole expression is founded on a fallacy, even in its latest form.

Reduced to its "lowest terms," the problem is this: A tube of small uniform bore, with its axis in one plane and of any form (*i. e.*, any smooth curve), is kept rotating with a constant angular velocity, ω, about a vertical axis C, perpendicular to the plane of the axis of the tube. A small particle, nearly fitting the tube and of mass $= M$, is free to move along it, without friction, subject to no dynamic influences save from the tube and its motion; (we neglect gravity since motion is confined to a horizontal plane). If, in passing a certain point, 1, of the tube, at a distance r_1 from C, the velocity of the particle along the tube (*i. e.*, its relative velocity) is c_1, it is required to find its relative velocity c_2 when it reaches some other point, 2, of the tube, having given ω, c_1, r_1, r_2, and the form of the tube (if necessary) between 1 and 2.

Weisbach's solution of the above is given in the equation

$$M\frac{c_2^2}{2} - M\frac{c_1^2}{2} = \int_1^2 [\omega^2 M r]\, dr \qquad (1)$$

i. e.,

$$c_2^2 - c_1^2 = \omega^2 r_2^2 - \omega^2 r_1^2, \qquad (W)$$

his claim being that the change in relative velocity is solely due to a "centrifugal force" $\omega^2 M r$ (where r is the variable distance of the particle from C).

Now eq. (W) is the correct solution, as can be proved in the most detailed and rigorous manner (see p. 381, J. F. I., for May, 1887), but Weisbach's claim taken literally, as it would be by a student, is absurd, since the only force acting on the particle is the pressure of the side of the tube against it; while, if he is understood as asking us to grant that "the change in relative velocity is the same *as if* solely due," etc., he is practically begging the question, since few could be expected to give immediate assent to so sweeping an assumption, to yield which, virtually yields all.

Mr. Frizell's method of solution is identical with Weisbach's in assuming that a certain "centrifugal force" is the sole cause of the change in relative velocity, and is open to the same objection of making too long a stride at the outset. *His* "centrifugal force" is $[\omega - \omega']^2 M r$, (p. 68, of recent July number; an alteration from what he first maintained, on p. 31 of J. F. I., for July, 1884, now conceded to have been in part erroneous). Here ω', measured in a direction opposite to that of ω, is the angular velocity (about C) of M relatively to the tube, so that $\omega - \omega'$ is the absolute angular velocity of the particle at any instant. If w denotes the absolute velocity of the particle at any instant, and $90° - a$, the angle between w and r, we may write,

$$\omega - \omega' = \frac{w \cos a}{r} \qquad (2)$$

and hence, according to Mr. Frizell,

$$\frac{M c_2^2}{2} - \frac{M c_1^2}{2} = M \int_1^2 \frac{w^2 \cos^2 a}{r} d r \qquad (F)$$

which cannot be integrated unless w and a are known functions of r.

If "experiment is the court of last resort in disputed physical questions," let us be careful, in testing eqs. (W) and (F), to employ experiments, real or ideal, the facts in which are known with the greatest precision, and of such a nature that the blame of the slightest discrepancy between fact and formula must plainly be laid at the door of the "centrifugal term."

[The weak point in Mr. Frizell's claim that the Lowell experiments sustain his version of the "centrifugal term" in the "common theory" of turbines, is that, in making all discrepancies between experiment and formula chargeable to the "centrifugal

term," he not only calls upon us to grant his allowances for friction and the assumption of a five per cent. contraction at wheel-entrance to be correct, but virtually demands that the hypothesis of "laminated flow," which underlies the "common theory," shall be considered as very closely realized; whereas this supposition, which vastly simplifies hydraulic problems (and without which, in fact, we could hardly theorize at all in some instances), is well known to be only an approximation, which, in extreme cases (like Venturi's tube, for example), gives results differing by more than fifty or sixty per cent. from the truth, and requires corrective coefficients accordingly. It is therefore useless, in experiments with turbines of narrow crowns, to look for the effect of the "centrifugal term," entirely unmasked by other influences. Hence the necessity, in this purely theoretical problem of the tube and particle, of choosing test experiments involving but a single particle (instead of millions), moving without friction (and no one will deny that the results claimed would be precisely realized if friction could be entirely obviated).]

First Test.—Suppose that between the points 1 and 2 the tube is so shaped that the particle traverses it without contact with either side, and hence experiences no constraint from it whatever (horizontally). (That is, there need be no tube at all, but simply a smooth horizontal supporting surface between 1 and 2.) Its absolute path, then, between 1 and 2, must be *a straight line described with some constant* (absolute) *velocity* w (by Newton's first law of motion). Let the perpendicular distance from C to this straight line be a. Then

$$r_1 \cos a_1 = a, \text{ and } r_2 \cos a_2 = a; \tag{3}$$

while, from the two parallelograms of velocities,

$$c_1^2 = w^2 + \omega^2 r_1^2 - 2 w \omega r_1 \cos a_1 \tag{4}$$

$$c_2^2 = w^2 + \omega^2 r_2^2 - 2 w \omega r_2 \cos a_2 \tag{5}$$

By subtracting (4) from (5), noting from (3) that

$$r_1 \cos a_1 = r_2 \cos a_2,$$

we obtain (as an experimental fact)

$$c_2^2 - c_1^2 = \omega^2 r_2^2 - \omega^2 r_1^2 \tag{6}$$

which is identical with what eq. (W) gives for this case (and for

every case); while eq. (F) is totally at variance with (6). For, with w constant and $\cos \alpha = a \div r$, [eq. (3)], we have

$$\int_1^2 \frac{w^2 \cos^2 \alpha}{r} dr = w^2 a^2 \int_1^2 \frac{dr}{r^3} = \frac{w^2 a^2}{2} \left[\frac{1}{r_1^2} - \frac{1}{r_2^2} \right];$$

i. e., introducing ω, for comparison, (F) becomes

$$c_2^2 - c_1^2 = \frac{w^2 a^2}{\omega^2 r_1^2 r_2^2} \left[\omega^2 r_2^2 - \omega^2 r_1^2 \right], \qquad (F')$$

the magnitude of the discrepancy depending on numerical data. Eq. (F) is therefore manifestly erroneous.

Second Test.—Suppose ω is made zero, *i. e.*, the tube to remain stationary, then the absolute is identical with the relative velocity at any point. For a frictionless stationary tube, it is an experimental fact that the absolute velocity remains constant, *i. e.*,

$$c_2 = c_1 \qquad (7)$$

Now eq. (W) with $\omega = 0$, gives $c_2 = c_1$, in exact accordance with fact whereas eq. (F), which does not contain ω, would assert that

$$c_2 > c_1 \qquad (F'')$$

and is again shown to be fallacious.

It is noteworthy in this second test that, since the tube is at rest, the position of the axis C can have no possible bearing on the result, a fact which confirms eq. (W) [from which r_1 and r_2 drop out], while according to eq. (F)

$c_2^2 = c_1^2 +$ a quantity dependent on the location of C; which is a manifest absurdity.

Another *reductio ad absurdum*, similar to the last, may be brought out by the following question, which I would like to propound to Mr. Frizell (and which is suggested by the circumstance that Mr. Frizell's "centrifugal term" does not reduce to zero when the Tremont turbine is held fast, at full gate, each wheel channel then becoming a stationary short pipe discharging water under a certain head):

If a short, straight pipe is fixed at an acute (horizontal) angle in the vertical side of a large stationary tank holding water, where should the vertical axis be taken in forming the "centrifugal term" which Mr. F.'s ideas compel him to incorporate in the formula for the discharge of this pipe?

It is, of course, true, as Mr. Frizell says, that if a body of mass M be compelled by a guide to follow a circular path of radius r, and has a velocity v in that path, then a centrifugal force of

$$\frac{Mv^2}{r}$$

is developed [by which we are to understand, with Rankine, that the guide sustains an outward (centrifugal) pressure of the above amount, and the body an equal inward (centripetal) pressure]. But if the body (like a water particle in a turbine) is *not* following this circular path, but *some other* (*absolute*) *path* (whose direction and sharpness of curvature are not mentioned, nor the absolute velocity w of the body in it), the assertion (of Mr. F.) that a "centrifugal force" of

$$\frac{Mv^2}{r}$$

is developed must certainly be taken *cum magno grano salis*, even if v *does* represent the component of w perpendicular to r (the other component being along r).

The reason for avoiding the phrase that an angular velocity is so many *feet* per second is this, that it is confusing to a student to tell him that while a *linear velocity* of two feet per second may also be stated as twenty-four inches per second, an *angular velocity* of two feet per second is not twenty-four inches per second, but two inches per second, or two miles per second, *i. e.*, the number 2 (so long as the second is the unit of time) is sufficient, and the employment of any unit of length is as superfluous as the use of a unit of volume or weight.

Niagara Falls, N. Y., July 28, 1887.

OBITUARY.

Pliny Earle Chase.

Pliny Earle Chase, a distinguished member of the Franklin Institute, and acting President of Haverford College, died on Friday, December 17, 1886, at his home on the college grounds. Pliny Earle Chase, the oldest son of Anthony and Lydia Earle Chase, was born at Worcester, Mass., August 18, 1820, and consequently, at the time of his death, was in his sixty-seventh year. He was graduated at Harvard College in 1839, and for some time thereafter devoted himself to teaching. His first engagement in this career was as the principal of a district school in Leicester, Mass.; subsequently he was appointed to the principalship of a school in Worcester. He came to Philadelphia, which was destined to be his future home, in 1841, and engaged in the same avocation; first, in the Friends' select school, and later in a private school of his own. On account of impaired health, he abandoned teaching in 1848, and was engaged in mercantile pursuits for some ten or twelve years. During this period, he carried on the stove and foundry business, under the firm names of North, Harrison & Co., North, Harrison & Chase, North, Chase & North, and Chase, Sharp & Thompson, the late John Edgar Thompson, President of the Pennsylvania Railroad Company, being a silent partner in the last-named firm.

In 1861, he again returned to teaching, succeeding the late Prof. C. D. Cleveland in the ownership of a prominent school for young ladies, at 903 Clinton Street, in Philadelphia.

In 1871, he received the appointment of Professor of Natural Science in Haverford College. He was afterwards transferred to the Chair of Philosophy and Logic, and at the time of his death, and for nearly a year prior thereto, he was the acting President of that institution. He also occupied temporarily the post of Professor in the University of Pennsylvania, made vacant by the death of Prof. John F. Frazer; and that of Lecturer on Psychology and Logic in Bryn Mawr College.

Prof. Chase's relations with the Institute date from 1851, in which year he became a member. He was elected a member

of the Board of Managers in 1864, and of the Committee on Publications in 1869, and served continuously in both offices until his death. He was frequently called upon to assist in the work of instruction, and his name appears on a number of the annual programmes as a lecturer, upon subjects relating, principally, to astronomy and meteorology. For a number of years, also, he prepared the scientific notes which have added much to the general interest of the JOURNAL, to which he was likewise an occasional contributor.

PROF. CHASE devoted much time to philosophical, philological and physical studies, and was esteemed universally as a scholar of extraordinary versatility, and as an original thinker of the highest order. The thoroughness and extent of his scientific work are shown by his numerous published writings, which include about 120 titles in the register of papers published in the *Transactions and Proceedings of the American Philosophical Society;* about fifteen articles in other periodicals, principally the *American Journal of Science* and the JOURNAL OF THE FRANKLIN INSTITUTE, and several small independent works, the last of which is his *Treatise on Meteorology.* This extensive list of publications bears evidence of the intense mental activity of his life. In the beginning, and occasionally all through the list of publications, we see his interest in the mysteries of the origin of language; his studies in Sanskrit, Chinese and Indo-European roots and analogues, were followed by a Copto-Egyptian vocabulary; but with slight exceptions, all of his works since those first years have been confined to problems in Cosmic, Terrestrial and Molecular Physics. In these departments, it has been not so much observation and experiment, but rather the search after theoretical relations and the deductive establishment of new principles that has chained his attention. It would seem as though to his mind the operations of Nature were conducted by the same laws, whether on the smallest or on the largest scale. Thus, from the motions in a small mass of resisting material, he deduced the sun's mass and distance; from the cosmic relations of gravitation and inertia in the solar system, he deduced the velocity of light; by studying the loci of planetary aggregation under the perturbing influence of Neptune and Jupiter on the asteroids, he predicted the location of an unknown planet.

In meteorology, his work includes the distribution of heat and barometric pressure; the polarization of sky-light; the periodicity in rainfall at Philadelphia and over the world; the effect of cosmic influences on meteorology; the relation of the aurora to rainfall; the laws of cyclonic and anti-cyclonic movements. In his meteorology, he has brought together a number of the more recent results of studies, especially those bearing on the local indications and general predictions of the weather, and, we are informed, has educated his scholars in a method of weather prediction based upon his tidal and harmonic tables. Unfortunately, however, these methods of prediction have in them too much that is empirical to justify their adoption by ordinary meteorologists. To the general reader his works undoubtedly seem imbued with the spirit of Kepler, and with his patience also, who toiled through innumerable speculative computations to eventually fall, most fortunately, upon the three laws that served Sir Isaac Newton as tests of the truth of his own brilliant inductions.

The general impression which the work of PROF. CHASE has made upon his scientific contemporaries is perhaps fairly expressed in the following abstract from a letter received by the Committee from a scientific man of eminent position and reputation, to whom the Committee had applied for data to aid in the preparation of the foregoing inadequate memorial:

"I comply with your request to contribute a few words upon CHASE'S scientific contributions, although I am no more worthy to pass judgment upon them than are the others to whom you have applied. I should be glad to examine his works in detail, more thoroughly, but their enormous extent utterly forbids my attempting it. I have in years past frequently read them with amazement, not understanding at all the logical process by which he arrived at his conclusions, many of which, however, served to confirm a principle recognized by mathematicians, namely, that a given law expressed in one set of terms will be found to be applicable to one class of natural phenomena, while the same law or equation will apply to another class of phenomena, if we merely attribute new and appropriate interpretations to the constants or data entering into the equation. On this principle Drummond, of late years, has developed his work on natural law in the spiritual world, and this seems to be the fruitful idea that pervaded the whole of PROF. CHASE'S publications."

In 1864, the American Philosophical Society, of which PROF. CHASE was one of the most active members, awarded him the "Magellanic Gold Medal," for his paper on "The Numerical Relations of Gravity and Magnetism."

In character, PROF. CHASE was one of the most lovable of men, and the following tribute to his memory from a brother professor will be warmly endorsed by all who knew him well:

"With the widest attainments in the field of knowledge, he preserved the greatest simplicity and humility. He was always ready to hear, and weigh fairly the opinions of others; and, when necessary to maintain his own, it was always done with modesty, courtesy and kindness. Retiring in his disposition, it was often difficult to draw forth an opinion from him. He was a member of the Society of Friends, and a thorough believer in its principles. The simplicity of his Christian faith and the beauty of his life must long be remembered by his friends." THE COMMITTEE ON PUBLICATIONS.

BOOK NOTICES.

THE SEPARATE SYSTEM OF SEWERAGE. By Cady Staley and Geo. S. Pierson, C. E. New York: D. Van Nostrand.

The authors of this work commence by calling attention to the imperative need of some system of sewerage as soon as population becomes aggregated within a limited area, the existing conditions being forcibly stated in the following passage: "An examination into the sanitary condition of a majority of our older cities and villages will show the great need of some kind of sewerage. Many of them have never taken any measures to rid themselves of the necessary accumulations of filth incident to a considerable population. For generation after generation, the refuse which should be removed from the dwellings, has been flung upon the surface of the ground, or into cess-pools, where the putrefying mass poisons the air and appeals in more ways than one for a remedy."

After pointing out the evils of the Combined System, the advantages of the Separate System are explained, and numerous tables are given, showing the rate of flow of liquids through pipes, etc., which indicate the scientific knowledge requisite to properly remove the liquid wastes from a given area.

The applicability of the Separate System is set forth as follows: "The introduction of the Separate System marks an important era in the development of sanitary drainage, recognizing, as no other system has, the prime importance of an early removal of household and industrial wastes, which are the main factors in soil pollution. That it will best meet the requirements of all large and densely populated cities (economy considered), is not probable. That, under competent advice, it can meet the requirements of *house*

drainage more perfectly in *any city* than the Combined System, cannot be denied. It is peculiarly adapted to many of the numerous smaller cities, which have been practically debarred from sewerage by its cost, and to outlying portions of larger ones. Its comparatively small cost permits an early and general extension, and the removal of domestic wastes before the soil has become saturated with them beyond a reasonable hope of purification."

This permanent pollution of the soil is a matter of the greatest importance, and the dangerous consequences are seen in the instances where the opening of the streets for the laying of gas or water pipes has been followed by sickness, in the adjacent houses, of a character that indicated that the emanations from the exposed earth were the cause.

The work is illustrated by cuts, showing the various flush tanks, etc., and also showing the practical details of laying sewer pipe. Forms for specifications are given, which render it a complete band-book for the practical engineer.

W. B. C.

BOILER-MAKING FOR BOILER-MAKERS. W. H. Ford, M.E. New York: John Wiley & Sons. 1887.

It is safe to say that this little book contains in clearly stated language more practical information than can be found in any other on its subject approaching its size.

It is addressed to practical workmen, and employs only terms and illustrations easily understood by them.

Whilst it embraces every point of importance in the art, every detail is promptly accessible through an unusually full and exact index.

The modest preface of three small pages shows the intention of the author to supply a real need of the craft for a concise, practical treatise within the easy comprehension of the workmen in the business. The book meets and fills the want. Keeping in mind that the author announces, "*this book is entirely devoted to the workshop*," there is very little that could profitably be added to it, unless perhaps a reduction of its few formulæ to expressions in purely arithmetical rules and terms with examples of their practical application for the benefit of those who were never taught or trained to appreciate anything resembling algebra, but who yet work safely and confidently with plain arabic figures. There are many men of such attainments among practical boiler-makers, and such an additional feature might be highly appreciated by them. Altogether, there are few books which present such full and exact knowledge, concisely stated in such a clear and readily accessible shape.

S. L. W.

GRIMSHAW'S PUMP CATECHISM. By R. Grimshaw, M.E. New York: Practical Publishing Company. 1887.

This book gives in compact shape much information that is directly to the point on the subject, which, when needed, is often required with an urgency that does not permit of a search through the many publications in which it is scattered.

It gives a plain and distinct showing of the construction and operation of the numerous hydraulic machines in general use, such as could only be had by the perusal of hundreds of advertising pamphlets and catalogues of rival manufacturers, the conflicting claims of many of which are confusing if not suggestive of unreliability, and is valuable in that it informs the reader what he may not expect to do with pumps as well as showing how to use them and the principles which govern their operation.

To the many manufacturers and others whose operations compel the use of pumps, such a book is a great benefit, its language is entirely within the comprehension of the class of persons employed about such work. In short it is a valuable addition to the author's series of practical popular books. S. L. W.

SCIENTIFIC NOTES AND COMMENTS.

PHYSICS.

SYSTEMS OF ELECTRICAL DISTRIBUTION BY ALTERNATING CURRENTS AND TRANSFORMERS.—In the London *Electrical Review*, March 18th to April 22, 1887, there is published a series of interesting articles by Rankin Kennedy, on "Electrical Distribution by Alternating Currents and Transformers," reprinted in the *Electrician and Electrical Engineer*, New York.

In a brief history of such systems, obtained apparently wholly from the record of English patents, he cites, as the earliest record, a patent to Jablochkoff, in 1877, for using induction coils with alternating or intermittent currents for distributing lamps. The transformers were placed in series, and were apparently used for obtaining a higher from a lower potential, as in the ordinary Rhumkorff coil. The next in order are the patents to Harrison, 3,470, of 1878, Bright, 4,219, of 1878, and Edwards and Normandy, 4,611, of 1878, the latter of which he says is important, as it is a clear and distinct description of a complete system. The coils are, in all of these, placed in series, and no mention seems to be made of converting high into low tension, other than a statement in Bright's patent that "the size and length of the primary wire and secondary wire coils are adapted to the number of lights employed." The next patent, No. 5,183, of 1878, to J. B. Fuller, of New York, seems to be the first to mention a regulating device by varying "the magnetic field." The next is that of De Meritens, 5,257, of 1878, which makes no advance on prior inventions. No other patents are mentioned prior to 1882, to Gaulard & Gibbs, which, he says, has "all the elements arranged precisely as in the systems patented or described by Jablochkoff, Edwards and Normandy, Bright and De Meritens." In another patent to Gaulard and Gibbs, 1884, he says that an attempt is made to prove that the transformers connected in series are self-regulating. The writer then states that in June, 1883, he, for the first time, described the actual effects of counter E. M. F., and stated that when the transformers are connected in parallel they became beautifully self-regulating. After he made this statement, Messrs. Zipernowski and Déri, of Buda Pesth, applied for a patent (No. 3,379, March 16, 1885,) for placing the transformers in parallel. He considers this to have been a great step in the

history of such systems, and claims that "no self-regulating transformer has been invented up till this date, which will give constant E. M. F. in the secondary circuit, with constant current in the primary circuit;" that is, when connected in series. He states the law that "as the current in the secondary circuit increases, the counter E. M. F. of the primary *decreases*, and, therefore, the current in the primary circuit increases," which law, he says, renders them perfectly adaptable to connection in parallel order to a supply at constant E. M. F. He states that the law is similar in every respect to that for motors in a continuous current circuit.

The next patent is that of Ferranti, No. 15,251, of December, 1885, the claims of which he gives in full, "to show what can be put into a British patent." It contains transformers in parallel and other accessory devices. The next is that of Siemens and Halske, No. 16,038, of 1885. The United States Gaulard and Gibbs patent is dated October 26, 1886.

In the patent of Edwards and Normandy, as well as in that of Ferranti, it was proposed to employ a converter for raising the potential of the (low potential) dynamo current, and from this converter to supply the other converters in the system. Such a system was constructed by the writer (Kennedy), in 1886, with an alleged loss of less than two per cent. in the first transformers, in which the dynamo potential of fifty volts was raised to 2,000.

In his history of such transformers, the writer does not offer any records of the invention of one of the chief and essential parts of such transformers, that of reversing the function of the well-known induction coils, and thereby converting a high tension into a low tension current of great quantity. He states at the end of his article, merely that "there is an impression abroad" (by which he undoubtedly refers to the United States) "that the mere employment of the fine wire as primary and the thick as secondary in an induction coil was a great invention made only recently, I am certain that this has been tried by innumerable experimenters during the past thirty years." It is to be regretted that he did not furnish some proof of at least one of the "innumerable" cases. In the absence of such proof, it may be of interest to quote here, from the JOURNAL OF THE FRANKLIN INSTITUTE, May, 1887, p. 357, in which Prof. Elihu Thomson, in referring to some lectures which he had delivered at the INSTITUTE ten years ago, says: "After showing the induction coil as so used, I reversed the process and passed high potential discharges from a charged battery of leyden jars, through the fine wire coils of the induction coil, and received currents of low potential but of great volume from the coarse wire of the coil. By putting a low resistance galvanometer in the circuit of the coarse wire, known ordinarily as the primary, a strong deflection of the index of the galvanometer took place, and upon bringing the ends of the coarse wire coil together in slight contact, a bright green flash took place at every leyden jar discharge through the fine wire."

It may also be of interest, in this connection, that Alexander Bernstein, of Boston, applied for a U. S. patent in January, 1883, for such a system, but it was rejected, on the ground that "it is not apparent how applicant in any case can get more quantity from a secondary coil than he has in his primary," by which, we presume, quantity of current is meant, as distinguished from quantity of energy.

In the history of the transformers themselves, Kennedy begins with the form invented by Faraday, in 1835, which consists of an iron-ring core, the two halves of which are wound, respectively, with the two wires, resembling, therefore, a Gramme ring without commutator, and having its endless winding cut at two points, thus forming two separate coils. This form is a very good one, as the closed magnetic circuit of the lines of force is composed entirely of iron; although much older than the simple magnet form used in the Rhumkorff coil (1842) or in the Gaulard and Gibbs system, it is much better than the latter, as they have open iron magnetic circuits, instead of having the whole magnetic circuit of iron.

He goes on to describe the "evolution" of the modern transformer from that of Faraday by the inventions of Kennedy, 1883; Ferranti, 1885; Stanley 1886; Dick and Kennedy, 1886, and Zipernowski and Déri, 1885, the best and "most novel" development being in the latter, which is the "highest class of transformer, reducing the magnetic resistance to a very small value." This invention consists in forming the two conductors into what might be termed a core of ring form and then overwinding them with iron wire; in fact, it is the transformer of Faraday turned inside out—instead of the conductors enclosing the iron, the iron encloses the conductors. Such transformers exhibit no external (wasted) magnetism, and, therefore, represent the greatest economy of magnetism.

In this history of the "evolution" of the transformer, the writer appears to neglect dates, as the alleged improvements of Ferranti, Stanley and Dick and Kennedy appear to have been invented after the Zipernowski and Déri, and were, therefore, steps in a backward direction. Furthermore, the writer does not seem to be aware of the fact that in the English patent of Staite, No. 12,212, of 1848, an induction coil precisely like that of Zipernowski and Déri is distinctly shown, described and illustrated, the only unessential difference, considering it as an inductor merely, is that it contained only one coil instead of two, the object of it being to increase the self-induction of that one coil. The placing of the iron around the ring-form conductor is, therefore, older perhaps than some of the later inventors of inferior devices.

Kennedy's later form called a sub-divided transformer, appears to be a novel and ingenious improvement of the Zipernowski and Déri or Staite sheathed coil, as any or all of the sub-divided coils are accessible and may be removed or cut out in case of damage without unwinding all the iron wire covering.

After describing a few more of the latest forms of transformers, he concludes his history by saying "the introduction of this system in America has created a somewhat amusing flutter among the electrical fraternity." We agree with him, and recall here a statement made in the FRANKLIN INSTITUTE JOURNAL some time ago, regarding these systems: "It is not very creditable to the Americans to bring before the public as new, a system which has been known and used in Europe for a number of years past."

He concludes his interesting articles with rules of construction, among which are the following: "To be self-regulating for supplying a constant potential and varying quantities of current, the transformers should have the

primary coils connected in a multiple arc system in which the mains have a constant potential. The lengths of wires must be found for self-regulation according to the laws:

(1.) When no work is being done in the secondary circuit, there should be no current in the primary circuit; that is, the counter pressure in the primary must be equal to the primary pressure, or very nearly equal thereto.

(2.) As the current increases in the secondary circuit, the current in the primary should increase proportionally in the ratio of the transformer; that is, the counter pressure in the primary should fall as work is increased in the secondary.

"All transformers working in one system must be constructed accurately with a fixed ratio."

Rule 1.—To find the lengths of the primary and secondary conductors in a transformer for reducing from a high to a low pressure, divide the primary pressure by the coefficient of induction in the primary circuit (that is, by the induction in volts per foot of wire), this will give the length in feet of wire for primary.

Rule 2.—Divide the secondary pressure by the coefficient of induction in volts per foot, this will give length in feet of wire for secondary.

In the best transformers working with about 200 alternations per second this coefficient is very high and averages about two volts per foot, and that may be taken as the figure for use in the above rules; for example:

Given a primary pressure of 1,200 volts, and the required secondary pressure given as 80 volts, what lengths of primary and secondary wire should be employed?

Answer, $\frac{1,200}{2} = 600$ feet for primary, $\frac{80}{2} = 40$ feet for secondary.

These lengths do not include wire not under induction.

If the alternations are not so rapid this coefficient becomes less. It might be argued from this fact that as it is perfectly easy to make the alternations very much more rapid than 200 per second, that, say 500 or 1,000 alternations should be adopted. There is a limit to that; as the alternations increase in number per minute the losses in the transformer increase, and that fact often accounts for different efficiencies being found for the same transformer by different experimenters—the one, perhaps, has employed the alternations for which the transformer was calculated, the other has employed slower alternations and therefore no agreement could be come to. It is, therefore, necessary to ascertain by experiment the coefficient of induction for each type of transformer at a given alternation rate. In transformers with long magnetic circuits, common to all the coils of wire, the coefficient will not be higher than 1·5, and often falls as low as one foot per volt.

Practically this coefficient may be found by taking the given alternating pressure having the given rate of alternations through an approximately correct length of primary wire on the transformer, say a length calculated at two volts per foot (the secondary circuit being open or not yet wound on), and measuring the current produced through this length. If no measurable current

is observable then that is the correct length; there should be some current, of course, say, perhaps, two per cent. of the maximum current. If the coefficient of induction is less than that calculated upon, a considerable current passes in the primary when no secondary current is flowing. The primary wire must, in that case, be increased in length until this initial current disappears, or becomes so small that it is of no account, and then the length of secondary can be calculated by the rule.

Rule 3.—The ratio of a transformer is found by dividing the primary pressure by the secondary pressure, thus in my previous example:

$$\frac{1,200}{80} = 15.$$

15 would be said to be the ratio of that transformer, and thus

	Primary.		*Secondary.*
The pressures are to each other as	15	to	1
The lengths of conductors to each other as	15	"	1
The cr. ss-section of conductors to each other as	1	"	15
The currents to each other as	1	"	15

The iron conductor of magnetic force should not at any time be anywhere near half saturation; it should therefore have large cross sections, and data for calculating its size may be obtained from dynamo builders."

In another article on induction coils, by Gisbert Kapp, in *Industries*, reprinted in the London *Electrical Review*, April 22 and 29, 1887, pages 366 and 390, the writer makes the following statements:

"A person having no theoretical acquaintance with the behavior of alternating currents, would compute the rate of doing work" (*i. e.*, the power) "in the circuit by simply measuring the current (say, with a Siemens dynamometer), and the terminal pressure of the machine (say, with a Cardew's voltmeter), and multiply the two. The product he would, generalizing from his experience with continuous current machines, consider equal to the rate of doing work. But this would be completely wrong, because he would have neglected the time element."

"A ring-shaped inductor, wound in the Gramme fashion, that is, with the iron inside and the copper outside," (*i. e.*, Faraday's form,) "will not be as economical in weight of materials used as the inverse arrangement of copper coils inside and iron wire wound over them to form the outside" (*i. e.*, Zipernowski and Déri, or Staite form).

He shows from theoretical deductions that transformers connected in series cannot be made self-regulating for giving a constant potential in the secondary, unless approximately when the amount of iron is small and oversaturated. That such a transformer may have its secondary coil short-circuited without the current in it becoming very great. That the characteristics of transformers in parallel is a straight line, and that it therefore is perfectly self-regulating for constant potential. C. H.

CHEMISTRY.

PHOTOGRAPHY BY VITAL PHOSPHORESCENCE.—Dr. Jno. Vansant publishes the following observations in the St. Louis *Photographer*, July, 1887: Some months ago, there was published in several scientific journals,* an article in which I showed how excellent photographic positive prints, on glass or paper, could be made from an ordinary negative by means of the transformed or "stored-up" radiant energy—the phosphorescent luminosity—of certain inorganic substances, especially particular sulphides of calcium and strontium.

Many organic substances also, as is well known, possess this property of storing-up, so to speak, and afterwards emitting, as more or less luminous rays, the radiations to which they have been exposed. Crystallized carbon, in form of the diamond, and white paper may be cited as illustrations of this class. A photographic latent image on a bromide of silver surface, capable of being developed, can easily be produced by bringing into *contact*, for an hour or so, in the dark, such a sensitive surface, and an engraving, or some ordinary printing, on white paper which has been just previously exposed for some minutes to the direct rays of the sun.

But I have now to call attention to the curious fact that the kind of light given out by certain *animal organs*, and which evidently in its causation has some close relation to the nervous system and vitality of the animal, and belongs to a different class of phenomena from the phosphorescence above mentioned, can also bring about incipient decomposition in a haloid salt of silver. Moreover, it can do this through a sheet of glass of the usual thickness used for photographic negatives, and, consequently, there is a possibility of producing by such light photographic positive prints.

The following experiment, copied from my notes, proves this:

June 8, 1887.—This evening, just after dark, I took about a dozen fire-flies (*Lampyris corusca*), which had been captured a few minutes before on the lawn, and enclosed them in a wide-mouthed vial of some three ounce capacity, having a piece of fine white bobinet (such as is used for ladies' veils) stretched over its mouth in place of a stopper. Enclosed thus, they would frequently emit the momentary flashes of greenish-tinted yellow light for which they are remarkable, though usually only one insect at the same time would flash. Every few seconds one or another would emit its light for a period, which I estimated to average in each case about one-half of a second, and the frequency of the emissions could be increased by gently shaking the vial. When not flashing, the under surface of the three posterior segments of the fire-fly's abdomen, from which the light came, was scarcely at all luminous, but was simply of a bright yellow color. The flashing was plainly under the control of the insect, like its muscular movements. These fire-flies are rather less than three-quarters of an inch long, and the segments which become luminous have, altogether, an area of only about one-eighth

* *Scientific American Supplement*, February 12, 1887; Philadelphia *Photographer*, April 16, 1887.